

THE CONSEQUENCES OF NUCLEAR WAR ON THE GLOBAL ENVIRONMENT

HEARING BEFORE THE SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES NINETY-SEVENTH CONGRESS SECOND SESSION

SEPTEMBER 15, 1982

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(III)

THE CONSEQUENCES OF NUCLEAR WAR ON THE GLOBAL ENVIRONMENT

WEDNESDAY, SEPTEMBER 15, 1982

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT,
Washington, D.C.

The subcommittee met, pursuant to call, at 10:05 a.m., in room 2325, Rayburn House Office Building, Hon. Albert Gore, Jr. (chairman of the subcommittee) presiding.

Mr. GORE. The subcommittee will come to order. I would like to welcome our witnesses and guests.

Thirty-seven years ago, a nuclear device packing the yield of 12,500 tons of TNT was detonated 1,900 feet above Hiroshima with effects unprecedented in human warfare. Today, that same device would equal one-half of the area destructive force of the smallest warhead on a U.S. nuclear reentry vehicle.

As the size of both the United States and Soviet nuclear arsenals have grown, increased concern has focused on the immense death total that would accompany a nuclear exchange. However, of late, that same intensity of concern has focused on the longer term consequences of nuclear war for any human survivors.

What would the Earth be like after a nuclear exchange? Is it possible that the destructive forces unleashed by a war could damage the environment in such a fundamental way as to disrupt the delicate balance of life that exists on Earth? Could such a war, as some have claimed, deplete the Earth's ozone layer and allow levels of ultraviolet radiation to reach the Earth which could blind all unprotected eyes, humans and animals alike? Or, could such a war, as others have claimed, produce long lasting forest and oilfield fires whose smoke could significantly disrupt the food growing cycle by reducing the amount of sunshine penetrating through to the Earth? Also, how would the Earth's delicate ecosystems be affected by a blanket of ionizing radiation capable, perhaps, of killing or mutating some orders of plant and animal life, while leaving other forms less impaired?

These are some of the sobering questions we hope to address at this hearing. In addition, we will explore some of the health perils awaiting survivors of a nuclear war. With medical supplies in short supply and radiation levels impairing outside activity for weeks or maybe months, would mankind be able to cope after a nuclear war? Or, as some have claimed, will the collapse of public health safeguards and the presence of primitive sanitary conditions, cou-

pled with survivors' greater susceptibility to illness because of exposure to radiation, mean that previously vanquished diseases will again rage at epidemic levels?

What we hope to gain from this hearing is a better understanding of the health and ecological consequences of a nuclear war and to better understand where the gaps in our knowledge are and how we can best fill those gaps.

Because of the apocalyptic nature of this subject, most of the theories now being propounded obviously cannot be confirmed through the normal scientific method. However, the absence of confirmatory data has not slowed the escalating concern within the scientific communities. Not only have scientists within this country raised profound questions as to the environmental and health consequences of a nuclear war, but, in addition, we are advised that such concern is shared by scientists worldwide, including scientists in the Soviet Union.

At international meetings that have been held for decades by leading international scientists, the consequences of nuclear war have been debated and viewed with common alarm by participants, including leading international scientific figures from both the United States and the Soviet Union. Yet, within that country and within certain quarters of this country statements are made and preparations take place as if the national leaders believed that a nuclear war could be prosecuted with tangible spoils available to the victor.

If the results of a nuclear war mean ecological and medical disaster for all participants, we believe that message must obviously be conveyed to the decisionmakers of both superpowers. Unfortunately, unofficial symposia have not yet accomplished that goal. Accordingly, we must search for some more formal mechanism for communicating the nuclear foreboding already felt by most of the world's scientific community. We hope the issues considered today will help to dramatize the need for such a mechanism.

Now, without objection, I would like to include at this point in the record the statement of our ranking minority member, Mr. Walker.

[The opening statement of Mr. Walker follows:]

OPENING REMARKS BY REPRESENTATIVE ROBERT S. WALKER

MR. CHAIRMAN, I WANT TO JOIN YOU IN WELCOMING OUR WITNESSES HERE TODAY. OUR HEARING IS ONE WHICH ADDRESSES A TOPIC WHICH ONLY A FEW SHORT YEARS AGO WAS UNTHINKABLE - THAT ALL OF OUR EFFORTS TO PRESERVE THE PEACE MAY EVENTUALLY FAIL, AND THAT MANKIND MAY HAVE TO FACE THE REALITY OF SURVIVING BEYOND THE HOLOCAST.

AN ENTIRE GENERATION OF HUMANITY HAS LIVED IN FEAR OF THE NUCLEAR THREAT FOR MORE THAN THIRTY FIVE YEARS. REASONABLE MEN HAVE ALL AGREED THAT A NUCLEAR EXCHANGE IS UNTHINKABLE, AND THAT THERE COULD BE NO SUCH THING AS A "LIMITED" NUCLEAR EXCHANGE.

BUT WE ARE LEARNING THAT THERE ARE PRESSURES ON THE MARCH IN THE WORLD TODAY WHICH CAN, AND MAY, LEAD TO THE UNTHINKABLE. THE NUCLEAR CLUB IS NO LONGER LIMITED TO THE SUPERPOWERS. WE HAVE SEEN TOO MANY EXAMPLES OF SMALLER NATIONS DEVELOPING THE ABILITY TO PRODUCE THESE TERRIBLE ENGINES OF DESTRUCTION.

AND, WHERE ONCE THE THOUGHT OF A TERRORIST ORGANIZATION GETTING ITS HANDS ON A NUCLEAR WARHEAD AND HOLDING THE WORLD HOSTAGE WAS MATERIAL FOR A JAMES BOND THRILLER, TODAY THAT POSSIBILITY IS DEADLY SERIOUS.

AS MORE WEAPONS ARE PRODUCED THROUGHOUT THE WORLD THE POSSIBILITY THAT ONE, JUST ONE, WILL FALL INTO THE WRONG HANDS, OR THAT THE FAIL-SAFE SYSTEMS WILL MALFUNCTION BECOMES HIGHER AND HIGHER.

FINALLY, WE CANNOT IGNORE THE FACT THAT WE ARE AT A GREAT DEVIDE IN THE AFFAIRS OF NATIONS. IT IS NO SECRET THAT OUR OWN DEFENSE CAPABILITIES WERE ALLOWED TO SLIP TO TRULY FRIGHTENING LEVELS. WE ARE NOW ENGAGED IN A LONG AND COSTLY CAMPAIGN TO

REGAIN PARITY WITH THE SOVIETS, BUT THAT WILL TAKE TIME. THOSE WHO STUDY THE KREMLIN CANNOT HELP BUT NOTICE THAT THERE IS A NEW WILLINGNESS ON THE PART OF THE SOVIET LEADERSHIP TO IMPOSE MILITARY SOLUTIONS TO POLITICAL PROBLEMS. FOR MORE THAN THIRTY-FIVE YEARS THE SOVIETS WERE WILLING TO SEEK THEIR GOALS WITHOUT DIRECT USE OF THE RED ARMY. THEY FOUND SURROGATES TO OVERTHROW DEMOCRATIC GOVERNMENTS THROUGHOUT THE WORLD. THEY WILLINGLY PROVIDED THE WEAPONS, THE TRAINING AND THE FINANCING FOR REVOLUTION IN ALL OF THE FAR CORNERS OF FREEDOM, BUT THEY DID NOT BECOME DIRECTLY INVOLVED.

ALL OF THAT CHANGED IN AFGANISTAN. THOSE ARE NOT SURROGATES FIGHTING TO CRUSH FREE MEN, IT IS THE CREAM OF THE SOVIET ARMY, AND THEY ARE USING EVERYTHING SHORT OF NUCLEAR WEAPONS.

IT IS NOT DIFFICULT TO SEE THAT THE SOVIET UNION IS IN A POSITION WHERE THEY SEE THE OBVIOUS. TODAY WE ARE AT A LOW POINT IN OUR ABILITY TO DEFEND OURSELVES AND OUR ALLIES. THE AMERICAN GOVERNMENT HAS LAUNCHED A MAJOR PROGRAM TO IMPROVE OUR DEFENSES AND TO REGAIN PARITY WITH THE SOVIETS, BUT THAT PROGRAM WILL TAKE TIME TO ACCOMPLISH. THERE HAS BEEN A FUNDAMENTAL CHANGE IN SOVIET POLICIES WHICH IS EVIDENCED BY THE FACT THAT FOR THE FIRST TIME SINCE WORLD WAR II THE SOVIETS HAVE BEEN WILLING TO COMMIT THE RED ARMY TO COMBAT IN AFGANISTAN.

ONE CANNOT HELP BUT WONDER IF, IN THIS NEW ERA OF ACTIVE SOVIET MILITARY ADVENTURISM, IF SOVIET STRATEGISTS MUST NOT BE TAKING A CAREFUL LOOK AT THE CURRENT SITUATION AND WONDERING IF THIS IS NOT THE BEST TIME IN TWENTY YEARS, AND PERHAPS FOR YEARS TO COME, TO TEST OUR RESOLVE REGARDLESS OF THE CONSEQUENCES?

BUT, AS LONG AS THIS NATION IS GOVERNED BY MEN OF GOOD WILL WHO SEEK TO PRESERVE THE PEACE AND TO SAFEGUARD ALL MANKIND WE HOPE AND PRAY THAT WE WILL NEVER HAVE TO SEE THE CONSEQUENCES OF NUCLEAR HOLOCOST.

BASED ON STUDIES I HAVE SEEN IT APPEARS THAT THE PROBABLE CONSEQUENCES ARE SO TERRIBLE THAT THEY MAY NOT EVEN BE IMAGINABLE BECAUSE WE JUST DON'T HAVE ENOUGH DATA AND EXPERIENCE TO MAKE THE RIGHT ASSUMPTIONS NOW. IN ANY CASE, THE AFTERMATH OF A NUCLEAR EXCHANGE IS PROBABLY SO TERRIBLE THAT THE LIVING MAY WELL ENVY THE DEAD.

THERE IS A MERIT IN HEARINGS SUCH AS OUR HEARING TODAY IN THAT THEY SERVE TO REMIND ALL OF US HERE TODAY HOW TERRIBLE THIS NUCLEAR SWORD OF DAMOCLES TRULY IS. WE HAVE REVIEWED STUDIES FOR THIS HEARING WHICH INDICATE THAT WASHINGTON IS AT NO LESS RISK THAN MOSCOW, AND THAT THE LONG TERM RESULTS ARE TRULY TOO TERRIBLE TO CONTEMPLATE FOR EITHER SIDE.

THE BEST RESULT OF THESE HEARINGS WOULD BE TO REMIND EACH OF US IN THIS ROOM THAT WHILE WE MIGHT DISCUSS THE RESULTS OF NUCLEAR WAR IN AN ACADEMIC MANNER, THAT SUCH A WAR MUST REMAIN UNTHINKABLE. WE SIT IN THIS ROOM WHICH IS A CONSTANT REMINDER THAT MAN STANDS POISED READY TO LEAP OUTWARD UPON THE GREAT VOYAGES OF DISCOVERY TO NEW WORLDS AND NEW GALAXIES, AND WE ALSO HAVE THE ABILITY TO DESTROY OURSELVES IN A FEW SHORT MOMENTS SO THAT SOMEDAY, WHEN OTHER BEINGS REACH THIS PLANET THEY WILL REPORT THAT ON THE THIRD PLANET FROM THE SUN THERE ONCE WAS A THRIVING SOCIETY, IN A WORLD OF PLENTY, BUT THAT FOR REASONS UNKNOWN GREAT FIREBALLS SWEEPED THE PLANET LEAVING IT A BARREN PLACE NO LONGER FIT FOR HABITATION BY LIVING BEINGS.

Mr. GORE. I would like to welcome the members of our first panel, Dr. Sidney Drell, with the Stanford Linear Accelerator Center at Stanford University, and Dr. H. Jack Geiger, from the City College of New York, School of Biomedical Education. Gentlemen, welcome to both of you.

Today is going to be a little bit hectic. Because of the primary elections held around the country yesterday, most of the votes that would have normally taken place on Monday and Tuesday have been put off for early today. As a result, you are going to see us running in and out. I hope you won't be disconcerted by that. It is our belief that we can build an important record at this hearing which will contribute to a better understanding of the subject matter at hand.

In fact, there is a vote on right now, but in view of what is to come later on, I am going to skip this vote and stay here. But later on issues that are of substantially more significance will require my attendance on the floor. Others will help here in making certain that we have continuity in the hearing.

I would like to begin, Dr. Drell, with you. Let me say that I have enjoyed the opportunity to work with you, not just on this issue but on the strategic arms control issue. You have made a terrific contribution for quite some time to that debate. We appreciate your presence here today to discuss this subject.

Without objection, the entire text of your prepared statement will be put into the record in full. If you care to summarize any of it, that is fine. You don't have to. Whatever you think is the most forceful way to get your contribution across. So please proceed.

STATEMENTS OF SIDNEY D. DRELL, STANFORD LINEAR ACCELERATOR CENTER, STANFORD UNIVERSITY, AND H. JACK GEIGER, M.D., CITY COLLEGE OF NEW YORK, SCHOOL OF BIOMEDICAL EDUCATION

Dr. DRELL. Thank you, Mr. Chairman, for this opportunity to testify.

As a scientist, I know that data and experiments are the most important ingredients in the study of physical phenomena. Everything we learn in science, the very core of our understanding, comes from our observations and our data.

In my testimony today I address the consequences of a major nuclear war. Happily, we have no data in terms of which to describe these consequences. Therefore, there is little for me to offer by way of definite conclusions or predictions. What I can do best as a scientist is to set the scale and describe the unprecedented destructive potential of a nuclear holocaust. I can list the great uncertainties, the vast imponderables, and the overall helplessness of society to escape to the sidelines or avoid devastation if nuclear war were to occur.

The picture I will present was summarized very well in the preamble of the resolution on nuclear war and arms control which was passed overwhelmingly by members of the National Academy of Sciences at the annual meeting in April. It said simply: Nuclear war is an unprecedented threat to humanity; a general nuclear war could kill hundreds of millions and destroy civilization as we

know it; any use of nuclear weapons, including use in so-called limited wars, would very likely escalate to general nuclear war; and science offers no prospect of effective defense against nuclear war and mutual destruction.

Recall the enormity of the destructive potential in existing nuclear arsenals. All of World War II added up to 6 megatons, which is not as large as one of the large nuclear warheads now deployed. Today's totals exceed 10,000 megatons or a million Hiroshimas, as you described, Mr. Chairman. Official estimates are that a combined total of more than 200 million United States and Soviet citizens would be killed outright in a major nuclear exchange which was designed to kill civilians. The initial survivors, a very large number of whom would be seriously injured, would face the longer term, more subtle, but nonetheless hideous effects of radioactive fallout and infectious diseases, such as cholera and dysentery, due to poor sanitation. And this is a prospect they would face without anything like adequate medical support.

The radioactive fallout is a new feature of nuclear weapons. A ground burst of 1 megaton will make 1,000 square miles of the Earth's surface uninhabitable for unsheltered human beings for a period of several weeks or longer.

The medical consequences of the ionizing radiation following a global nuclear war can be estimated using actual data from the Hiroshima and Nagasaki explosions. This permits conservative estimates to be made of the subsequent incidence of fatal cancers, genetic defects in children of survivors, and sterility. Medical specialists such as Dr. Geiger will discuss the seriousness of this massive insult to the human gene pool in later testimony.

I want to move to surprises and chance discoveries. The effect of deadly, widespread fallout was discovered in the 1954 Bikini test of a 15-megaton bomb, contaminating the Japanese fishing boat *Lucky Dragon* 90 miles downwind and the Rongelap Atoll 100 miles from the burst point. This was the most dramatic illustration of the potential for large-scale nuclear war to kill and to maim on a worldwide scale far beyond the local effects of blast and fire alone.

Other chance discoveries were also made during the testing of large nuclear weapons in the atmosphere in the decade before such testing was banned by the Limited Test Ban Treaty of 1963. They include, for example, EMP, the electro-magnetic pulse effect.

In a 1976 pamphlet the Arms Control and Disarmament Agency of the U.S. Government emphasized the fact that much of our knowledge was gained by chance and went on to say—"this should imbue us with humility as we contemplate the remaining uncertainties (as well as the certainties) about nuclear warfare."

At that time the Director of ACDA was Dr. Fred Ikle, who is currently the Under Secretary of Defense for Policy in the Pentagon. In his foreword to that pamphlet he wrote—and I quote Dr. Ikle—

Uncertainty is one of the major conclusions in our studies, as the haphazard and unpredicted derivation of many of our discoveries emphasizes. Moreover, it now appears that a massive attack with many large-scale nuclear detonations could cause such widespread and long-lasting environmental damage that the aggressor country might suffer serious physiological, economic and environmental effects even without a nuclear response by the country attacked.

Consider next atmospheric changes. Beyond the radioactive fallout, there are other sources of widespread, long lasting and potentially catastrophic environmental damage. One effect that is believed to be of major importance and has been discussed extensively is the disturbance of ozone in the stratosphere. If the ozone shield in the stratosphere is reduced, an increased flux of ultraviolet radiation from the Sun will reach the Earth's surface. The resulting adverse consequences include increased incidence of skin cancer in fair-skinned races and decreased crop yields. Damage to different species of biological and plant organisms will vary considerably, depending on their physical characteristics.

Another possible result of a major nuclear war is the igniting of tremendous fires that may burn for weeks in vast forests, croplands, and urban and industrial areas. The small particulates, or aerosol, produced by the fires and forming the thick smoke layer will drastically reduce the amount of sunlight reaching ground. The actual level of darkening of the sunlight at the Earth's surface can be very different depending on unknown factors, such as the total area that is burning. A recently published analysis indicates that this effect could be very serious and might reduce sunlight at the Earth's surface by more than a factor of 100. Furthermore, these fires could persist for months and completely disrupt, if not totally eliminate, agricultural production in the northern hemisphere if they occurred during the growing season. From this follow other consequences of social and economic disruption, not to mention the psychological strain of such a massive trauma to all the survivors.

It is both numbing and frightening to realize that there exists even the possibility through these fires of reducing sunlight to the Earth's surface by an amount comparable to that which one current theory now believes was responsible for causing the extinction of the larger vertebrates and dinosaurs 65 million years ago.

One can, to be sure, speculate about very different nuclear war scenarios with limited counterforce strikes, effective operation of antiballistic missile defenses, and widespread availability and extensive use of civil defense shelters. Are these, in fact, likely or even real possibilities? Again, one cannot be sure. In the absence of data, we know no more about how a nuclear war might begin or end than we do about its overall consequences. There are, however, some important considerations to keep in mind.

First, there is a great danger that once the vital interests of the United States and the Soviet Union are engaged to the point that either initiates a nuclear attack, both countries will dig even deeper into their vast arsenals of more than 50,000 nuclear weapons. Neither past experience and precedent, nor war gaming, gives cause for much hope that the nuclear exchange and resulting devastation would remain limited and aimed exclusively at counterforce and direct military targets.

In addition, there is no technical basis for any confidence that it will be possible to control the escalation of a limited nuclear conflict. There are just too many opportunities during combat for confusion and error. Once the nuclear threshold is crossed, there will inevitably be a broad delegation down the line of authority for nuclear release. This will be required by the very short missile flight

times and by the potential vulnerabilities of any conceivable worldwide command and control and communication system from a national command center to the broadly dispersed military units with thousands of nuclear weapons. For these reasons, both human and technical, a limited nuclear war seems a most improbable event.

This view was echoed by Gen. David C. Jones, former Chairman of the Joint Chiefs, when he left office in June—and I quote General Jones: "I don't see much chance of nuclear war being limited or protracted."

Second, there is no defense, no effective defense, against nuclear retaliation. This was recognized 10 years ago when we signed the SALT I treaty that severely limits ABM deployments. On technical grounds today, I still see no prospect of deploying—on ground or in space—an effective defense of the Nation's people and industry.

Third, I cannot conceive of a civil defense system that could protect either the Soviet or American society from unprecedented and unacceptable disaster and devastation in all-out nuclear war. Calculations that are cited to illustrate the effectiveness of civil defense in saving lives differ in detail and draw widely different conclusions as to fatality levels. However, they all have one feature in common; namely, their conclusions are critically dependent on a number of assumptions:

Are the cities directly targeted or just military-industrial targets; what is the total megatonnage; are the bombs air burst or ground burst to produce maximum fallout; what are the wind patterns and weather conditions; is the attack retargeted against the relocated population; does the attack occur during evacuation when masses of people are out in the open with no shelter; and how long will people actually remain in their expedient shelters while the deadly levels of radioactivity gradually die out over a period of weeks?

For the life of me, I cannot understand how anyone can say, in the face of all the unknowns about the consequences of nuclear war, and of all the uncertainties in the effectiveness of civil defense, that with adequate civil defense preparations the United States would be able to recover from an all-out nuclear war in 2 to 4 years. But that is what T. K. Jones, the current Deputy Under Secretary of Defense for Strategic and Theater Nuclear Forces has said, as reported in the Los Angeles Times last January.

In the same article in the Times, the Federal Emergency Management Agency, FEMA, responsible for our civil defense, is quoted as saying: "With reasonable protective measures, the United States could survive nuclear attack and go on to recovery in a relatively few years."

It is a good antidote to such outrageous claims to quote a conclusion of the sobering study called "The Effects of Nuclear War," published in 1979 by the Congressional Office of Technology Assessment. And I quote:

The effects of a nuclear war that cannot be calculated are at least as important as those for which calculations are attempted. Moreover, even these limited calculations are subject to very large uncertainties * * * This is particularly true for indirect effects such as deaths resulting from injuries and the unavailability of medical care, or for economic damage resulting from disruption and disorganization rather than direct destruction.

To summarize then, Mr. Chairman, I stress again that the problem with all precise nuclear war scenarios, with their neat assumptions and predictions, is that we fortunately have no data. In real wars, the nonnuclear conflicts of past experience, we have learned to appreciate that the course of events is determined by vitally important factors such as surprise, individual bravery, motivation, and luck. These are not in the theoretical scenarios. Maybe that is also why there are so few detailed calculations for real nonnuclear conflicts. The imaginary scenarios and computer printouts of casualty levels seems to proliferate only when there are neither data nor experience to test them against. I am reminded of the remark by Rebecca West who wrote that: "Before a war, military science seems like a real science, like astronomy; but after a war, it seems more like astrology."

Perhaps the best comment on nuclear war was made by President Eisenhower 26 years ago, in the very early days of the hydrogen bomb. In 1956 he noted that "We're rapidly getting to the point that no war can be won." President Eisenhower went on to observe further that war was no longer a battle to exhaustion and surrender, but that the outlook now comes close to "destruction of the enemy and suicide."

Since then, all we have done is to increase the level of potential devastation by many orders of magnitude as the nuclear arsenals have grown to more than 50,000 nuclear weapons which, if they are unleashed, will obliterate our civilization built over the centuries by the human spirit and human genius.

Thank you.

[The prepared statement of Dr. Drell follows:]

OPENING STATEMENT

TO

HEARINGS ON THE CONSEQUENCES OF NUCLEAR WAR ON THE GLOBAL ENVIRONMENT

before

The Subcommittee on Investigations and Oversight

of

The House Committee on Science and Technology

by

Sidney D. Drell

September 15, 1982

Thank you for the opportunity to testify on the very important subject of the consequences of a nuclear war. I am a physicist and a professor at Stanford University. Over a period extending 22 years, I have served in various capacities as an advisor and consultant to the White House, the Congress, and various government agencies and executive departments on matters of national security and arms control. As a scientist, I know that data and experiments are the most important ingredients in the study of physical phenomena. Everything we learn in science - the very core of our understanding - comes from our observations and our data.

My testimony today addresses the consequences of a major nuclear war. Happily we have no data in terms of which to describe these consequences. Therefore, there is little for me to offer by way of definite conclusions or predictions. What I can do best as a scientist is to set the scale and describe the unprecedented destructive potential of a nuclear holocaust. I can list the great uncertainty, the vast imponderables, and the overall helplessness of society to escape to the sidelines or avoid devastation if nuclear war were to occur.

The picture I will present was summarized very well in the preamble of the RESOLUTION ON NUCLEAR WAR AND ARMS CONTROL, which was passed overwhelmingly by the members of the National Academy of Sciences at its annual meeting last April. It said simply:

o nuclear war is an unprecedented threat to
humanity;

- o a general nuclear war could kill hundreds of millions and destroy civilization as we know it;
- o any use of nuclear weapons, including use in so-called "limited wars", would very likely escalate to general nuclear war;
- o science offers no prospect of effective defense against nuclear war and mutual destruction.

I have appended to my prepared statement for entry into the Record a copy of this Resolution, which calls on the United States Congress, the President, and other world leaders "to intensify substantially, without preconditions and with a sense of urgency" efforts to reduce nuclear weapons and reduce the threat of nuclear war.

CASUALTY LEVELS

Recall the enormity of the destructive potential in existing nuclear arsenals. The sum total of munitions expended over a period of six years in World War II added up to approximately 6 megatons (MT). That is less than the megatonnage of one of the large nuclear warheads now deployed. Hiroshima and Nagasaki were devastated by "relatively small" bombs whose yields were roughly 15 kilotons. The totals today exceed 10,000 MT!

About 90% of this unprecedented level of explosive energy would be released in intense heat and blast waves that would cause immediate devastation in the target areas. I wouldn't advise anyone to be within 10 miles of one MT! Official estimates are that a combined total of more than 200 million United States and Soviet citizens would be killed outright in a major nuclear exchange which was designed to kill civilians. The "initial" survivors, a very large number of whom would be seriously injured, would face the longer term, more subtle, but nonetheless hideous, effects of radioactive fallout and infectious diseases (such as cholera and dysentery) due to poor sanitation; and this is a prospect they would face without anything like adequate medical support.¹

¹ A recent study published in *AMBIO*, the International Journal of the Royal Swedish Academy of Sciences (Vol. XI, No.2-3, 1982), estimates that 750 million people would be killed outright by the effects of blast alone if all the 1124 major cities of the northern hemisphere were targeted by approximately 2000 MT on 5000 nuclear warheads. In addition, 340 million more would be seriously injured. This would leave roughly 200 million people, or about 15% of the urban population in the northern hemisphere, initially unharmed.

RADIOACTIVE FALLOUT

The dosage of fallout will be particularly large and threatening on a global scale if the nuclear bombs are detonated on the earth's surface or at low altitudes. In this case, vast quantities of the earth's soil and rocks will be vaporized by the heat pulses along with the radioactive bomb debris. Mixed together, they will rise with the fireball and form the characteristic mushroom cloud before settling back to earth. The heavier particles start settling within several hours as fine, deadly radioactive ash. For each one MT detonated this ash, driven by the wind, will typically make 1000 square miles of the earth's surface uninhabitable to unsheltered humans for several or more weeks. The lighter particles rise into the stratosphere, circulating the world for months and even years before returning to ground as world-wide fallout.

The medical consequences of the ionizing radiation following a global nuclear war can be estimated using actual data from the Hiroshima and Nagasaki explosions. The Japanese experience was the first extensive experience with sub-lethal and lethal effects of total body exposure in man and permits conservative estimates to be made of the subsequent incidence of fatal cancers, genetic defects in children of survivors, and sterility. Medical specialists will discuss the seriousness of this massive insult to the human gene pool in later testimony. In addition, the fallout will cause devastation to natural plant and animal communities, thereby entering the human diet, as well as disrupting agricultural growth.

SURPRISES AND CHANCE DISCOVERIES

The effect of deadly, widespread fallout was discovered in the 1954 Bikini Test of a 15-MT bomb, contaminating the Japanese fishing boat Lucky Dragon 90 miles downwind and the Rongelap Atoll 100 miles from the burst point. This was the most dramatic illustration of the potential for large-scale nuclear war to kill and to maim on a world-wide scale far beyond the local effects of blast and fire alone. Other chance discoveries were also made during the testing of large nuclear weapons in the atmosphere in the decade before such testing was banned by the Limited Test Ban Treaty of 1963. They include the discovery following high-altitude bursts of a widespread electromagnetic pulse, or EMP, that can wreck electrical command, control, and communication equipment; of the blackout of high-frequency radio communications; and of the production of the Van Allen belt, an artificial belt of charged particles trapped in the earth's magnetic field.

In a 1976 pamphlet ("Worldwide Effects of Nuclear War - Some Perspectives"), the U. S. Arms Control and Disarmament Agency (ACDA) emphasized the fact that much of our knowledge was gained by chance, and went on to say that this "should imbue us with humility as we contemplate the remaining uncertainties (as well as the certainties) about nuclear warfare." At that time, Dr. Fred Ikle, currently Under

Secretary of Defense for Policy, was Director of ACDA. In the foreword he wrote to this pamphlet he observed that:

"Uncertainty is one of the major conclusions in our studies, as the haphazard and unpredicted derivation of many of our discoveries emphasizes. Moreover, it now appears that a massive attack with many large-scale nuclear detonations could cause such widespread and long-lasting environmental damage that the aggressor country might suffer serious physiological, economic, and environmental effects even without a nuclear response by the country attacked."

ATMOSPHERIC CHANGES

Beyond the radioactive fallout, there are other sources of widespread, long-lasting, and potentially catastrophic environmental damage. One effect that is believed to be of major importance and has been discussed extensively is the disturbance of ozone in the stratosphere. In particular, if there is a massive exchange of high-yield weapons of one or more megatons, there will be a substantial injection of nitric oxide (NO) into the stratosphere with subsequent depletion of its ozone layer for a period extending several years. If the ozone shield in the stratosphere is reduced, an increased flux of ultraviolet radiation from the sun will reach the earth's surface. The resulting adverse consequences include increased incidence of skin cancer in fair-skinned races and decreased crop yields. Damage to different species of biological and plant organisms will vary considerably depending on their physical characteristics. As will be discussed later in today's hearings, there is uncertainty about the actual level of ozone depletion and also about the sensitivity of this effect to the mix of low- and high-yield nuclear weapons that are detonated.

Another possible result of a major nuclear war is the igniting of tremendous fires that may burn for weeks in vast forest, cropland, and urban and industrial areas. The small particulates, or aerosol, produced by the fires and forming the thick smoke layer will drastically reduce the amount of sunlight reaching ground. The actual level of darkening of the sunlight at the earth's surface can be very different depending on unknown factors, such as the total area that is burning, but recently published analyses indicate that this effect² could be very serious. It is estimated that the sunlight could be reduced by a factor as large as 150. The fires could persist for months and completely disrupt, if not totally eliminate, agricultural production in the northern hemisphere if they occurred during the growing season. From this follow other consequences of social and economic disruption, not to mention the psychological strain of such a massive trauma to all the survivors.

² P. Crutzen and J. Birks in the issue of AMBIO cited earlier.

There are evidently great uncertainties in our ability to predict the death and devastation, the disruption of the ecosphere, and the pattern, or even the possibility, of post-attack recovery after a nuclear holocaust. We are still learning of new effects - such as the importance of the darkening of sunlight due to massive fires - that should increase our "humility as we contemplate the remaining uncertainties (as well as certainties) about nuclear warfare."

It is both numbing and frightening to realize that there exists even the possibility that vast forest fires triggered by nuclear war could reduce sunlight reaching ground in the northern hemisphere by a comparable factor to that which, according to recent theory, may have led to the extinction of the larger terrestrial vertebrates, including the dinosaurs, 65 million years ago in the aftermath of an impact by a large extraterrestrial body.³

PROSPECTS FOR LIMITED WAR AND PROTECTION

One can, to be sure, speculate about very different nuclear war scenarios with "limited" counterforce strikes, effective operation of anti-ballistic missile (ABM) defenses, and widespread availability and extensive use of civil defense shelters. Are these, in fact, likely, or even real possibilities? Again, one cannot be sure. In the absence of data, we know no more about how a nuclear war might begin or end than we do about its overall consequences. There are, however, some important considerations to keep in mind when contemplating propositions such as limited and survivable nuclear conflict.

There is great danger that, once the vital interests of the United States and the Soviet Union are engaged to the point that either initiates a nuclear attack, both countries will dig even deeper into their vast arsenals of more than 50,000 nuclear weapons. Neither past experience and precedent nor war-gaming gives cause for much hope that the nuclear exchange and resulting devastation would remain limited and aimed exclusively at counterforce and direct military targets. In addition, there is no technical basis for any confidence that it will be possible to control the escalation of a limited nuclear conflict. There are too many opportunities during combat for confusion and error. Once the nuclear threshold is crossed, there will inevitably be a broad delegation down the line of authority for nuclear release. This will be required by the very short missile flight times and by the potential vulnerabilities of any conceivable world-wide command, control, and communication system from a national command center to the broadly dispersed military units with thousands of nuclear weapons. For these reasons - both human and technical - a limited nuclear war seems a most improbable event. This view was echoed by General David C. Jones, former Chairman of the Joint Chiefs

³ L. Alvarez, W. Alvarez, F. Asaro, and H. Michel, SCIENCE, Vol. 208, 1980.

of Staff, when he left office in June:

"I don't see much chance of nuclear war being limited or protracted."

There is no effective defense against nuclear retaliation. This was recognized 10 years ago when we signed the SALT I treaty that severely limits ABM deployments. During the past decade improved radar, interceptor, and computer technologies have enhanced the capabilities of terminal ABM for hard targets. This is particularly true for low-value targets so that the defense can be effective even if there is a significant leakage. However, on technical grounds, I see no prospect of deploying - on ground or in space - an effective defense of the nation's people and industry.

I cannot conceive of a civil defense system that could protect either the Soviet or American society from unprecedented and unacceptable disaster and devastation in all-out nuclear war. Calculations that are cited to illustrate the effectiveness of civil defense in saving lives differ in detail and draw widely different conclusions as to fatality levels. However, they all have one feature in common; namely, that their conclusions are critically dependent on a number of assumptions:

- o Are cities directly targeted or just military-industrial targets?
- o What is the total megatonnage?
- o Are the bombs air-burst or ground-burst to produce maximum fallout?
- o What are the wind patterns and weather conditions?.
- o Is the attack retargeted against the relocated population?
- o Does the attack occur during evacuation when masses of people are out in the open with no shelter?
- o How long will people actually remain in their expedient shelters while the deadly levels of radioactivity gradually die out over a period of weeks?

For the life of me, I cannot understand how anyone can say, in the face of all the unknowns about the consequences of nuclear war and of all the uncertainties in the effectiveness of civil defense, that with adequate civil defense preparations the United States would be able to recover from an all-out nuclear war in 2 to 4 years. That,

however, was the message of T. K. Jones, Deputy Under Secretary of Defense for Strategic and Theatre Nuclear Forces, as reported in the LOS ANGELES TIMES last January. In the same paper, the agency responsible for civil defense, the Federal Emergency Management Agency, is quoted as saying "....with reasonable protective measures the United States could survive nuclear attack and go on to recovery in a relatively few years."

It is a good antidote to such outrageous claims to quote a conclusion of the sobering study, "The Effects of Nuclear War", published in 1979 by the Congressional Office of Technology Assessment:

"The effects of a nuclear war that cannot be calculated are at least as important as those for which calculations are attempted. Moreover even these limited calculations are subject to very large uncertainties.... This is particularly true for indirect effects such as deaths resulting from injuries and the unavailability of medical care, or for economic damage resulting from disruption and disorganization rather than direct destruction."

SUMMARY

I stress again that the problem with all precise nuclear war scenarios, with their neat assumptions and predictions, is that we fortunately have no data! In real wars - the non-nuclear conflicts of past experience - we have learned to appreciate that the course of events is determined by vitally important factors such as surprise, individual bravery, motivation, and luck. These do not appear in theoretical scenarios! Perhaps that is why there are so few detailed calculations and claims for such conflicts. The imaginary scenarios and computer printouts of casualty levels seem to proliferate only when there are neither data nor experience to test them against. I am reminded of the remark by Rebecca West who wrote that:

"Before a war, military science seems like a real science, like astronomy; but after a war, it seems more like astrology."

Perhaps the best comment on nuclear war was made by President Eisenhower 26 years ago in the very early days of the hydrogen bomb. In 1956, he noted that:

"We're rapidly getting to the point that no war can be won."

Eisenhower went on further to observe that war was no longer a battle to exhaustion and surrender but that the outlook now comes close to "destruction of the enemy and suicide."

Since then all we have done is to increase the level of potential devastation by many orders of magnitude as the nuclear arsenals have grown to more than 50,000 nuclear weapons which, if they are unleashed, will obliterate our civilization built over the centuries by the human spirit and human genius.

NATIONAL ACADEMY OF SCIENCES

2101 CONSTITUTION AVENUE
WASHINGTON, D.C. 20418

April 27, 1982

RESOLUTION

NUCLEAR WAR AND ARMS CONTROL

--Whereas nuclear war is an unprecedented threat to humanity;

--Whereas a general nuclear war could kill hundreds of millions and destroy civilization as we know it;

--Whereas any use of nuclear weapons, including use in so-called "limited wars," would very likely escalate to general nuclear war;

--Whereas science offers no prospect of effective defense against nuclear war and mutual destruction;

--Whereas the proliferation of nuclear weapons to additional countries with unstable governments in areas of high tension would substantially increase the risk of nuclear war;

--Whereas there has been no progress for over two years toward achieving limitations and reductions in strategic arms, either through ratification of SALT II or the resumption of negotiation on strategic nuclear arms;

Be it therefore resolved that the National Academy of Sciences calls on the President and the Congress of the United States, and their counterparts in the Soviet Union and other countries which have a similar stake in these vital matters;

--To intensify substantially, without preconditions and with a sense of urgency, efforts to achieve an equitable and verifiable agreement between the United States and the Soviet Union to limit strategic nuclear arms and to reduce significantly the numbers of nuclear weapons and delivery systems;

--To take all practical actions that could reduce the risk of nuclear war by accident or miscalculation;

--To take all practical measures to inhibit the further proliferation of nuclear weapons to additional countries;

--To continue to observe all existing arms control agreements, including SALT II; and

--To avoid military doctrines that treat nuclear explosives as ordinary weapons of war.

Mr. GORE. Thank you. That was excellent testimony.

We will save questions until Dr. Geiger has completed his statement.

Dr. Geiger, thank you for coming. Without objection, your prepared text will also be put into the record at this point. We are honored to have you with us here today. For a lot of people, the physicians movement was an important breakthrough in looking at this subject in a realistic and objective way. A lot of people are indebted to you for the important role you have played in creating this wave of new awareness in the country regarding this most serious problem we face.

If you want to summarize any of your statement, we invite you to do so.

Dr. GEIGER. Thank you, Mr. Chairman, and thank you for this opportunity.

It has been almost four decades, in fact, since physicians began to study and analyze the medical and related consequences of the use of atomic bombs on Hiroshima and Nagasaki, and it has been more than two decades since physicians in the United States first published their findings on the medical effects of thermonuclear weapons in a variety of scenarios of nuclear war. And since those first publications 20 years ago, the scenarios have steadily gotten worse, the stockpiles have gotten larger, the bombs have gotten bigger, the warheads have gotten more varied, the missile delivery systems and other weapons delivery systems have gotten more sophisticated, more swift, more accurate, there has been a geometric increase in destructive power, and we are trapped in a kind of continuous and ongoing analysis just to keep up on both the medical and environmental effects.

In all of that time and in all of that change, however, our conclusions and the conclusions of the biophysicists, the biologists, the environmental scientists, have never varied. They have uniformly, each time around, come to the realization that nuclear war presents a threat to human life that is absolutely without precedent in the history of the species. Even the explosion of a single, 1 megaton weapon would be an event for which there is no antecedent, quantitatively or qualitatively, that the immediate and long-term dangers, some of which we are going to focus on today, are so overwhelming that, even though we cannot describe all of them with precision, they are grim and unforgiving in terms of our future. They mean that there can be no effective recovery, no return to a prenuclear normal, and that the very meaning of survival as we will see today, I think, will have changed.

The evidence suggests that the concept of survivability itself, which is central to both our military and our civil defense planning, is a fantasy. There is no remedy. The only hope is prevention.

We have spent a lot of time in recent years running the city-by-city scenarios, in part because that is the only way to make nuclear war comprehensible. When one gets to figures of 100 and 200 million deaths and more, it is beyond the capacity of most of us to absorb. So we do, in a way, the absurd—the 1-megaton, one-city cases. Even those are almost unmanageable. If we were to do a ground burst today on a clear day, of just 1-megaton, an air burst on a clear day today of 1-megaton, over New York City, during

working hours, and if as is likely a fire storm developed that covered some 250 square miles, there would be just over 2 million human beings killed immediately and another 3.4 million profoundly injured. All together, there would be 5.4 million casualties, or about 33 percent of all of the 16 million people in the New York metropolitan area.

Among those survivors, in addition to all the skull fractures and burns and paralyzing lesions of the spinal cord, crushing injuries and penetrating wounds, hemorrhage and shock, in addition to those there could be as many as 750,000 people with third degree burns over 25 percent of their body surface or more. I don't know of any way, medically, to visualize three-quarters of 1 million people with third degree burns, let alone three-quarters of 1 million people in one place at one moment in time. That is one weapon and one bomb.

But realistically, what we have to try to consider is not just one weapon on New York but multiple weapons on New York or London or Leningrad, Washington or Moscow, not one target but many, not one strike but several, not 3 to 7 days advance warning but almost none—not air bursts but, as Dr. Drell has indicated, mixtures of air bursts and ground bursts.

Even though we have concentrated on these kinds of single-city scenarios for illustrative purposes, we have always known that a longer time span and a much broader frame of reference is necessary, medically and biologically, if we are really going to estimate the consequences of a nuclear war, the consequences to human life, and indeed, the human species.

Those are some of the things we are going to hear about today, and my task, very briefly, is to try and provide some of that broader biological and medical frame of reference. The things we will be hearing about in detail from the testimony of later panels includes the problems of persistent and pervasive ionizing radiation and the contamination by that radiation, the food chain upon which all human life depends, the outbreak of epidemic disease among survivors on an enormous scale, and the consequence of radiation-induced impairment of our ability to fight infection and resist, the consequence of malnutrition, compromised sanitation, the explosive proliferation of flies, cockroaches and other radiation-resistant insect vectors—we can be sure, whatever happens to mankind, that the cockroaches will survive—and the collapse of medical and other social support system.

Next, the disruption and partial depletion of the ozone layer, the admission of penetrating ultraviolet radiation, with direct and immediate harm—including burns and blinding—not only to humans but to other mammals, other species in the food chain, and to plants and agriculture; hemisphereic or global climatic change of the kind that Dr. Drell has described as a consequence of massive forest fires and the injection of particulate matter into the atmosphere.

To do all of this, we have to begin to understand and we have to try to divide and think of the medical effects in particular of nuclear war occurring in a set of stages. One does not, in fact, have to be sophisticated in radiation biology or know all of the terms of radiation damage or physics to understand what radiation and these

other things will do to human beings. Let me briefly describe these stages after a nuclear attack, a thermonuclear explosion.

In the initial stage, the first 2 weeks or so after the attack, which is the period of the greatest number of prompt casualties and deaths, 90 percent of those will be due to blast injuries and burns, and about 10 percent due to radiation.

Then a second stage, an intermediate stage, running, let's say, from week three to week eight. This is the main period for deaths due primarily to radiation exposure, a time when people who were radiated during the attack will die in very large numbers if they have been exposed to a median lethal range of radiation, about 450 rems, for health adults. And we will come to the meaning of that in a moment.

In the late stage, from 2 months to 20 weeks, the radiation-injured survivors, if they have made it this far, tend to improve. Complications and difficulties supervene at this point for the burn and blast victims that are still alive.

Everything beyond 20 weeks we call a delayed stage, and here is where we will begin to see in significant numbers the effects of radiation exposure to fetuses in utero, at the time of the nuclear attack. That is going to appear as increased prenatal and perinatal death, death of the fetus and death shortly after birth, increased mental retardation, infants born with microcephaly shrunken heads and other abnormalities. A dose of 100 rads—and that is not a big dose—in a nuclear war to fetuses in utero will cause somewhere between 1 and 20 extra perinatal deaths in every 1,000 live births, and between 1 and 20 extra cases of mental retardation. If we take the middle figure and say, OK 10, this represents a 40 percent increase in the pre-attack perinatal death rate and 125-percent increase in the rate of retardation.

Then we come to the long-term stage, from that point to years to decades after the attack. Here we start seeing the late effects of radiation exposure, including damage to the skin, the lungs, the gonads, the eyes—including cataracts—fibrosis of various body organs, and vascular effects.

But the most striking effects will be an increase in cancer in adults. On the average, for every 80 people exposed to 100 rads, one will subsequently die of radiation-induced cancer. These will start to occur as soon as 2 years after the nuclear war for acute leukemia in the young and those under 15, and as long as 20 or more years later for skin and lung cancer in others.

More striking than this, I think, in this delay period, this long-term period, will be the increase of cancer in children. That is a theme that will be recurring as we look at other effects. Infants and children are far more susceptible to radiation than adults, at any given level of radiation. Their bodies are smaller and any given dose is a bigger dose to their bone marrows than to ours. They have more rapidly growing tissue, which is radio-sensitive. With healthy adults, you and I in this room, with 200 rads of exposure, we would all probably survive. With 200 rads, most healthy infants and children would all probably die.

In the United Kingdom now—and the United States is roughly the same—one child in 2,000 dies of cancer before the age of 10. If those children are exposed to only 5 rads, a very small figure, that

rate will increase tenfold to 5 cancer deaths in every 1000. And for fetuses, we give them risks at 5 rads of the biblical level of plague, that 1 in every 10 of the children born so irradiated as fetuses will get cancer.

We know this not only from general biological and medical knowledge, not only from the Hiroshima and Nagasaki studies, but from our experience in this country, the cancer experience of children particularly in the counties of Utah and elsewhere, the high fallout downwind areas in the years of above-ground atomic testing in Nevada between 1951 and 1958. The cancer and leukemia death rates of children from that area in those years was 2.4 times the cancer death rate in children from the same area 6 years earlier or in children from the same area 6 years later after the atmospheric testing had stopped. The epidemiologic evidence suggests that we might use this as one, and maybe the only, credible definition of a limited nuclear war. It was the assault of the residents of Utah and other downwind areas by years of weapons testing in the atmosphere.

Finally, genetic effects, about which we know very little in these long-term periods. We do know that we can double the spontaneous mutation rate with only about 100 rads, and that in a single one-megaton bomb—not the bigger war we are describing—there would be 3,070 or so square miles exposed to that level of radiation and that risk of subsequent genetic defect.

Now, when you try and add all of this up in a bigger scenario—and that has been done recently, a most recent go around to try and keep pace with the stockpiling by a group of Europeans and American scientists—and published in *Ambio*, the journal of the Royal Swedish Academy of Sciences. They noted that by 1985, the total combined megatonnage of the United States and the Soviet Union will be nearly 13,000 megatons, in some 24,000 strategic and 35,000 tactical warheads. They didn't use in their hypothetical scenario a big fraction of that, but only about 5,700 megatons, less than half the total arsenal, and only one-fourth of the combined total of warheads, on population centers and military targets and oil fields and the like.

What is the consequence? The total population targeted is more than a billion, 1,300 million, roughly. Of these, 750 million would be killed and 340 million seriously injured by blast alone; 200 million would be safe initially. In a matter of moments, we would have wiped out two-thirds of the urban populations, and of the survivors, more than half would be injured. That is without counting burns, which would increase those figures enormously.

What about the radiation and other delays effects? Even assuming that people stayed indoors continually for 7 days, if there was an indoors to stay in, and that they could survive indoors for that time, in the first 6 to 8 weeks after this nuclear war there will be more than 1 billion deaths due to radiation in North America, Asia, Europe, and the Soviet Union. In North America alone, 19 million people will die of radiation effects, and an additional 62 million will suffer significant radiation illness.

Assuming the same protection factors, more than 5 million people in the northern hemisphere will die of cancer as a result of fallout exposure, in addition to 17 million who will be sterilized by

radiation, and ultimately between 6 and 16 million people will suffer some genetic effect in succeeding generations because of the exposure of their parents.

But these figures—and here we come to the core of what I want to say today—these figures are without consideration of the other factors, except for radiation, that we will be talking about today. They are without consideration of the probability of epidemic disease, the return of plague, typhus, rabies, massive gastro-intestinal disease and the like. They are without consideration of the effects of disruption of the ozone layer. They are without consideration of changes in the Northern Hemisphere's climate as a result of massive forest fires. They are without consideration of disruption of the social fabric.

The implication of these new and additional considerations that we will be hearing about today is that nuclear war changes the meaning of survival for human beings. Survival is not a matter of some short-term biological body count of the kind the military, civil defense, and even on occasions we in science and medicine give for convenience. It is not a matter simply of being alive or even uninjured a day or a week or a month or a year after a nuclear war. Survival for individual human beings as well as for the species, for mankind, means the maintenance of a complex and fragile interdependence—we sit on top of a food chain—an interdependence with other species in that food chain, an interdependence with the environment, an interdependence with agriculture and the chain of photosynthesis, an interdependence with microorganisms and, above all, an interdependence with each other, the maintenance of the social fabric which constitutes and supports our families, our communities, our economies, transportation, the production of food, education, medical care, communication and other complex systems.

In medical terms, the considerations you are going to hear about today change the definition of survival, or even of health. When we say someone is healthy, when we say somebody has the capacity to survive, we are describing that in the environment to which mankind adapted and in which mankind evolved. If we change that environment in significant ways, then all bets and all definitions are off. If the environment, to make this point clear, were suddenly—if all the land masses were suddenly to be covered by 20 feet of water, the definition of health would be the possession of gills. That is the way in which medical and health definitions are changed by some of these considerations today.

There is reason to believe, in fact, that it is not merely rhetorical to talk about the probability of failure of survival of the species. A recent demographic analysis by Dr. Jennifer Leaning of Physicians for Social Responsibility suggests that in our Nation, and perhaps in larger areas, the effect of a nuclear war of this size and the long-range effects that we're talking about today will reduce populations to the point—with infant mortality rates continuing to be so high, with depressed fertility, with all of the other consequences that we're going to hear about—that they won't effectively be able to maintain themselves.

The end of the species does not come at the moment of the "On the Beach" syndrome, with the last couple or the last 20 people

waiting for the radiation or the starvation to get them. The end of the species is determined at some point well before that, when there are still millions of people alive, by what has happened to the environment, by the imbalance between fertility and mortality, and by the capacity to reproduce. There is a risk.

In conclusion, what does this mean? It means—and one needs to consider this in regards to civil defense and military scenarios—it means that there are two ways to kill most of the people in New York or Leningrad or Moscow or Washington. The first is to bomb those cities when everybody is there. The second is to bomb those cities after everybody has been moved somewhere else in some bizarre crisis relocation or other so-called civil defense scheme. All that will happen is that they will have survived only to die more slowly, just as surely, a little bit later on.

The civil defense postures toward these probabilities are, in my view, based on a dangerous and self-serving denial of probability at the best, and at worst, on systematic misrepresentation that borders on outright fraud. Let me give you one example.

The civil defense people are fond of saying, "We really don't have to worry about radiation that much. After all, 99 percent of it will be gone at the end of two weeks because radiation decays so rapidly." That is quite true. What they fail to make clear is that in many areas initial levels will be 10,000 rads or more, so high that the residual 1 percent will be enough to damage or even to kill. And for people in those areas, to say 99 percent of it will be gone, is like saying to a drowning man, "Don't worry, it will take me only a second to get you 99 percent of the way to the surface." I am going to leave you there, but that is, in fact, not very helpful.

Similarly, to give one more example of the civil defense so-called planning mode, the posture that says, "Yes, we acknowledge the possibility of some of these dangers, but just give us enough time and enough money and there is always a way to work out a plan. Give us \$4 billion and we'll think of something."

The only way accurately to characterize the planning mode in connection with the prospect for looking at today is to look at a specific instance. Say the prospect of blinding by penetrating ultraviolet radiation. The kinds of things I would expect on the basis of past performance would be for the civil defense people to say, "Well, what we need to do is plan. We recognize this may happen to all of the other animals. We recognize that they may be blinded. What we had better do is manufacture and stockpile little sunglasses ahead of time, so that we can put them on all the animals afterwards."

There would be an alternative civil defense proposal, since I think that one is unweildly. We could afterward designate considerable numbers of human beings as "seeing-eye people" whose responsibility would be to lead around the cows, the pigs, the horses, and the chickens that would have been blinded by the ultraviolet but on which whose survival we would depend for our food.

Finally, civil defense and some military people will say that we can't predict with certainty that the effects we're going to hear about today will occur, and we can't quantify the results. Well, no one can predict with certainty that you or I or T. K. Jones or Secretary Weinberger will die tomorrow, but no one can promise that

we will not die tomorrow. Therefore, I am sure that each of us has life insurance because we are prudent enough to assume the worst case, early death, rather than the best, unparalleled longevity, if not the kind of immortality that the civil defense people seem to assume. The prudent nation assumes the worst case. The prudent species does the same. It is too soon, obviously, to decide whether or not humankind is prudent, but the data to be presented today, in my view, make it clear that we should already been at the top of the endangered species list.

Thank you.

[The prepared statement of Dr. Geiger follows:]

Statement by

H. JACK GEIGER, M.D.

Biographical Sketch

H. Jack Geiger, M.D., M. Sci. Hyg., is currently the Arthur C. Logan Professor of Community Medicine, School of Biomedical Education, City College of New York. He received his M.D. degree from Western Reserve Medical School in Cleveland, Ohio in 1958, his M.S. degree in epidemiology from the Harvard School of Public Health in 1960, and from 1958 to 1964 trained in internal medicine on the Harvard Medical Service of Boston City Hospital and the Thorndike and Channing Laboratories of Harvard Medical School. Before assuming his present position, he was, successively, Professor and Chairman of the Department of Community Medicine, Tufts University School of Medicine; Visiting Professor of Medicine, Harvard Medical School; and Professor and Chairman, Department of Community Medicine, School of Medicine, State University of New York at Stonybrook.

In 1960, he was a founding member of Physicians for Social Responsibility, a national organization of physicians dedicated to professional and public education on the medical consequences of nuclear war, and in 1962 he was a co-author of the first published comprehensive study in the U.S. medical literature of the medical effects of a thermonuclear attack on American cities (New England Journal of Medicine, May 31, 1962). He has subsequently published or presented more than 30 papers, book chapters, etc. on the medical effects of thermonuclear weapons and nuclear war. He is currently a member of the Board of Directors and of the Executive Committee of Physicians for Social Responsibility.

He is the recipient of major awards from the American Public Health Association, the National Blue Cross-Blue Shield Associations of the U.S. and Canada, the National Association of Community Health Centers, and the Mississippi Association for the Health of the Poor for his contributions to the field of community medicine.

Almost four decades ago, physicians began to study and analyze the medical and related consequences of the use of atomic bombs on Hiroshima and Nagasaki. More than two decades have passed since physicians in the U.S. first published their findings on the medical effects of thermonuclear weapons in a variety of scenarios of nuclear war. With the relentless growth of superpower stockpiles, the enormously increased variety of nuclear weapons, the geometric increases in destructive power, and the unceasing development of ever more sophisticated, swift and accurate missiles and other weapon delivery systems, this sort of study and analysis has become an ongoing, continuous process not only for physicians but also for their colleagues in physics, biophysics, the biological sciences and the environmental sciences.

Over that time span, the scenarios have worsened, the totals have grown, and the analyses have become more complex, but for decades the conclusions -- from every medical and scientific discipline -- have never varied. Nuclear war presents a threat to life to an absolutely unprecedented degree; the explosion of even a single one-megaton weapon would be an event the effects of which have no quantitative or qualitative precedent in all of recorded human history. Both the immediate and the longer-term dangers we contemplate are -- even if we can only imperfectly estimate and describe them -- grim and unforgiving. There can be no effective "recovery", no return to pre-nuclear normal. The very meaning of "survival", as we shall hear in testimony today, will change. There is no remedy; the only hope is prevention.

For example, if that single one-megaton explosion were to be an air burst over New York City, on a clear day, a week day, during working hours, and if -- as is entirely possible -- a firestorm covering some 250 square miles developed -- just over 2 million humans would be killed immediately, and another 3.4 million people would be profoundly injured -- altogether, 5.4 million casualties, or 33.1% of the 16.3 million residents of the New York metropolitan area. Among the survivors -- in addition to all the skull fractures, paralyzing lesions of the spinal cord, crushing injuries of the chest and limbs, penetrating wounds, hemorrhage and shock -- there could be as many as 750,000 with third degree burns covering 25% or more of the body surface. There is simply no way, medically speaking, to visualize three quarters of a million people with third-degree burns. Yet the realistic threat we face (as do the people of London, Leningrad, Washington, Moscow or Berlin) is not one megaton but thousands, not one target but thousands, not one strike but many, not 3 to 7 days' advance warning but effectively none, not air bursts alone, but mixtures of air and ground bursts.

The death, devastation and desolation of such larger scenarios are so vast that physicians and other scientists, attempting to make nuclear consequences comprehensible, have tended in recent years to emphasize, for illustrative purposes, single-weapon one-strike examples; to draw the familiar concentric circles of the nuclear bullseye, and to focus on immediate and short-term effects.

But we have always known that a longer time-span and a much broader frame of reference, medically and biologically, is necessary for a true estimation of the consequences to human life and the human species of nuclear war. We have always known -- and have continuously attempted to predict -- that in addition to immediate effects, there will be longer-term biological, environmental and social consequences with major medical effects. The detailed testimony that will follow my comments will explore some of these dangers:

- (1) persistent and pervasive ionizing radiation, and the contamination of the food chain on which human life depends;
- (2) the outbreak of epidemic disease among survivors on an enormous scale, in consequence of
 - (a) radiation-induced impairment of the immune systems that fight infection
 - (b) malnutrition
 - (c) compromised sanitation
 - (d) the explosive proliferation of flies, cockroaches and other radiation-resistant insect vectors of disease, and
 - (e) the collapse of medical and other social support systems;
- (3) disruption and partial depletion of the ozone layer of the atmosphere and the consequent admission of penetrating ultra-violet radiation, with direct and immediate harm (including burns and blinding) to humans, other mammals, other species in the food chain, and to plants and agriculture;
- (4) hemispheric or global climatic change -- for example, the introduction of huge amounts of particulate matter into the atmosphere as a result of massive forest fires following a nuclear exchange, with reduction in sunlight and/or in average ambient temperatures and profound consequences to the ecosystem.

My purpose in these introductory remarks is to provide the longer and broader medical and biological frame of reference that is useful in understanding not only these specific dangers, but also the magnitude of the threat to our species that nuclear war involves.

It is useful to divide the medical effects of nuclear war into five stages:

(1) Initial Stage (weeks 1 and 2 after attack)

This is the period of the greatest number of casualties and deaths. More than 90 per cent of the deaths in this stage will be due to thermal and blast injuries, about 10% due to radiation.

(2) Intermediate Stage (weeks 3-8)

This is the main period for deaths due primarily to radiation exposure (during and shortly after the attack) in the median lethal range.

(3) Late Stage (weeks 8-20)

Radiation-injured survivors -- i.e., those who have made it this far -- tend to improve; severe complications may develop for burn and blast victims.

(4) Delayed Stage (more than 20 weeks)

Effects of radiation exposure of fetuses in utero begin to appear as: increased prenatal and perinatal death, increased mental retardation, infants born with microcephaly and other abnormalities. A dose of 100 rads to fetuses in utero will cause between 1 and 20 extra perinatal deaths in every 1,000 live births, and between 1 and 20 extra cases of mental retardation. If the mid-range figure of 10 extra cases per 1,000 live births is assumed, this would represent a 40% increase in the "normal" (pre-attack) perinatal death rate and a 125% increase in the rate of retardation.

(5) Longterm Stage

Here, from years to decades after the attack, are seen the late effects of radiation exposure, including damage to skin, lungs, gonads and eyes (including cataracts), late fibrosis and vascular effects. But the most striking effects will be:

(a) Increase in cancer in adults

On the average, for every 80 people exposed to 100 rads, one will subsequently die of radiation-induced cancer -- as soon as 2 years after exposure for acute leukemia in those under 15, as long as 20 or more years later for skin and lung cancer.

(b) Increase in cancer in children

Infants and children are far more susceptible to radiation than adults; because their bodies are smaller, at any given level of radiation they will receive a higher dose to the bone marrow and other highly susceptible tissue, and they have more rapidly-growing and therefore radiosensitive cells. So, at 200 rads, the average healthy adult will probably survive -- and the average healthy infant and child will probably die. The fetus and the very young infant are 10 times more radiosensitive than adults. So there will be an enormous increase in malignant disease in children. In the United Kingdom, for example, 1 child in 2,000 dies of cancer before the age of 10. An exposure to only 5 rads will increase this ten-fold, to 5 deaths in every 1,000. The incidence of cancer after radiation of the fetus (5 rads) may be as high as 100 per 1,000: every tenth child, the level of biblical plague.

We have already seen evidence of this effect in the United States, in the cancer experience of children in the high-fallout counties of Utah downwind from the atmospheric atomic test explosions in Nevada in 1951-1958. The cancer and leukemia death rates of area children in these years was 2.4 times the rate in children in the same areas in the preceding 6 years or in the following 6 years. The epidemiologic evidence suggests that here is the first credible definition of a "limited" nuclear war -- the assault on residents of Utah and other downwind areas by weapons' testing.

(c) Genetic effects

We have relatively little direct human data; we do know that the radiation dose estimated to double the spontaneous mutation rate in humans is about 100 rads. Following the explosion of a single one-megaton bomb in a surface burst, the area to which the fallout plume would deliver a dose of 100 rads or more in 7 days is 3,070 square miles.

What happens when we apply these calculations, in these stages, to a specified and realistic attack scenario? A group of scientists from the United States, the United Kingdom and other European nations published such calculations recently in Ambio, the journal of the Royal Swedish Academy of Sciences. They note that by 1985 the total combined megatonnage of the U.S. and the Soviet Union will be nearly 13,000 megatons, in some 24,000 strategic warheads and 35,000 tactical warheads. The nuclear war they envisage would use only 5,742 megatons -- less than half the total arsenal -- and only about 15,000 warheads -- only one-fourth of the combined total -- on military targets, population centers (1,124 cities), industrial and energy sites including oil fields, etc., almost all in the northern hemisphere.

Perhaps -- since only a moderate part of the total arsenal is used -- this is what some planners would call a "limited" nuclear war. What would the consequences be?

When all of the cities and towns are included, the scenario applies to a total population of some 1 billion 290 million. Of these, about 750 million would be killed and 340 million seriously injured by blast alone; 200 million would be safe, at least initially. In the few minutes of the war, the urban populations would be reduced by more than two-thirds; of the survivors, more than half would be injured.

Not only are these calculations conservative with respect to blast; these totals do not include the deaths and injuries due to burns.

And what of radiation and other delayed effects? Assuming that most immediate survivors stay indoors continuously for at least 7 days to minimize radiation effects, in the first 6 to 8 weeks after the nuclear war there will be more than 1 billion deaths due to radiation in North America, Asia, Europe and the Soviet Union. In North America, 19 million people will die and an additional 62 million will suffer significant radiation exposure.

In addition, assuming the same protection factors, by 10 to 20 years after the war, 5.4 million people in the northern hemisphere will die of cancer as a result of fallout exposure, 17 million people (including 3 million in North America) will be sterilized by radiation, and ultimately between 6 million and 16 million people will suffer some genetic effect in succeeding generations.

But these appalling totals are reached WITHOUT including any of the effects we will be discussing today! The calculations are made as if the bombs dropped, the war stopped, and nothing else happened except for the persistence of radiation. These totals -- dreadful as they are -- do not, for example, include estimates of deaths from massive post-war epidemics of gastro-intestinal disease,

plague, rabies and tuberculosis (the consequence of radiation-induced lowering of resistance to infection, malnutrition, etc.), which Dr. Abrams will describe.

Nor do they consider the possibility of ozone layer depletion, ultraviolet radiation, and blindness. As you will learn from Dr. Pitts, a reduction of 50 per cent in the ozone layer -- and that is possible -- would result in the almost certain blinding of most diurnal animals (and many humans without access to protective glasses) and profound damage to the ecosystem and to agriculture. The result would be a huge number of additional deaths from malnutrition and infection. The same effect -- additional deaths due to starvation -- could result from a new kind of darkness at noon: the disruption of sunlight and temperature norms by massive forest fires.

The implication of these new and additional considerations is that nuclear war changes the meaning of "survival" for human beings. Survival is not a matter of some short-term biological body-count -- simply being alive or even uninjured at 1 day, 1 week, or six months after a nuclear war. Survival -- for the individual as well as the species -- means the maintenance of a complex and fragile interdependence involving other organisms: the food and photosynthesis chains, beginning with plankton in the ocean, and including bacteria and viruses; interdependence with the environment, including agricultural plants, the water table and the like; and, above all, interdependence with other human beings -- the social fabric which constitutes and supports our families, our communities, our economies. For human beings, the true meaning of survival is also social -- transportation, communication, education, medical care and other complex systems. In medical terms, the definition of "survival" or even of "health" refers to the environment in which mankind evolved and to which it is adapted. If that environment is significantly changed, all definitions -- and all bets -- are off.

I have several times mentioned the survival of our species. I have not done so as a matter of mere rhetoric. The acute effects mentioned in the Ambio study, plus the considerations you will hear today, make it probable that a few years after a full-scale nuclear war the global population will be sharply diminished. And that population will be wracked with starvation and infection; birth rates and fertility will be depressed; malignancies will be abundant; agriculture may be in shambles. All of these factors will hit hardest at the very young; the survivors' futures -- their children -- will die before they do. A recent demographic analysis by Dr. Jennifer Leaning of Physicians for Social Responsibility raises serious questions about our capacity for demographic recovery.

If all this is likely, or even possible, then there are two ways to kill most of the people in New York or Moscow or Leningrad or London in a nuclear war. The first is to bomb those cities

while the populations are all still there. The second is to bomb them after all of their inhabitants have left for so-called "safe" areas in bizarre crisis relocation or other civil defense schemes. It is not merely the pragmatic impossibility of these plans that is at issue, nor the possibility that they will be fleeing precisely into the areas of most lethal fallout. It is, rather, the possibility that they will have "survived" only to die more slowly, though just as surely, a little later.

A few words should be said in closing about the "civil defense" and military postures toward these data and these possibilities. They are, in my view, based on a dangerous and self-serving denial of probability, at best, and at worst on systematic misrepresentations that border on outright fraud. As an example of the latter, consider the repeated civil defense reassurance -- in support of crisis relocation and sheltering -- that radioactivity decays rapidly and by the end of two weeks "99% of it will be gone." What they do not point out is that where the initial levels are very high -- as they will be in numerous areas -- the residual 1 per cent will still be so high as to be dangerous or lethal. It is really not much help to a drowning man to pull him 99% of the way to the surface.

Finally, civil defense and military critics will say that we cannot predict with certainty that these effects will occur, or even quantify the risks. Well, no one can predict with certainty that you, or I, or T. K. Jones or Secretary Weinberger will die tomorrow -- but no one can promise that we won't. Yet I am sure that each of us has life insurance, because we are prudent enough to assume the worst case -- early death -- rather than the best -- unparalleled longevity, if not immortality. The prudent nation assumes the worst case; the prudent species does the same. It is too soon, obviously, to decide whether or not humankind is prudent; but the data to be presented today, in my view, make it clear that we should already be at the top of the Endangered Species list.

Mr. GORE. Thank you for your excellent testimony.

I have a number of questions. I hardly know where to start. I was reading last night an article by Paul Crutzen and John Birks—and Professor Birks will be with us a little bit later. They begin their article with a statement that I think gives a useful perspective and a statement that I identify with: "The immediate effects of a global nuclear war are so severe that any additional, long-term effects might at first thought be regarded as insignificant in comparison. However, our investigation into the state of the atmosphere following a nuclear exchange suggests that other severely damaging effects to human life and the delicate ecosystems to which we belong will occur during the following weeks and months.

I think the question of perspective is one that is important.

The second point I wanted to start off with is that uncertainty plays an important part in an inquiry like this one, and in order to deepen our understanding of this subject, we have to acknowledge the magnitude of the uncertainties which exist, try to quantify them, and try to evaluate them.

Now, the immediate effects, as you said, Dr. Geiger, are just so totally and completely unthinkable that the inquiry could really stop right there, but the scientific inquiries have established that the damage would not stop right there. It would keep on going for a long time. Insofar as the unthinkable nature of those immediate effects has not served to sufficiently sober the decisionmakers in the superpower nations, perhaps it is useful to continue the inquiry and examine in more detail what those subsequent, longer term effects might be.

As we do so, we immediately encounter uncertainties. At one end of the scale some have argued, most recently Jonathan Schell in "Fate of the Earth," that there is a distinct possibility that all human life on this planet would end not long after a nuclear war between the United States and the Soviet Union.

Now, at the other extreme you have some folks in this administration, some folks elsewhere, undoubtedly many in the Soviet Union, who seem to believe that the long-term effects are not that significant. In the words of T. K. Jones, all you need is a little dirt to shovel on top of the hole in the ground that you have dug and then run your car over it.

Would both of you agree that the truth is probably somewhere in between, or would either of you say that there is a real likelihood of all human life being destroyed?

Dr. DRELL. I would put the probability in between because of the sensitivity of any prediction like Jonathan Schell wrote about to actually where war is fought and whether or not this fallout, this atmospheric disruption, this ozone depletion, were to spill over into the Southern Hemisphere. As I understand it, and it's not very well, there isn't that tremendous amount of coupling between the Northern and Southern Hemispheres because of the apparent east-west character of the weather.

I don't know. Maybe someone later today who is more qualified than I can answer. But as I think about the scenario, I am horrified enough by the fact that one can even raise the question that we are disturbing our environment on a scale so grave that the question of extinction can be raised; even on a scale, as I noted ear-

lier, that may have been responsible for the extinction of dinosaurs 65 million years ago.

I do not see the extensive coupling to the Southern Hemisphere. That is the only comment I would make.

Certainly T. K. Jones' statements are totally without basis. You can just look at any calculations that he has put into the Congressional Record over the past 10 years—and I have been involved in discussions of several of them—he chooses to ignore the retargeting; he chooses to ignore the surface versus air burst. And then he comes up with precisely the most fictitious of scenarios that you can dream up. I think there is zero value there. The only question I have is the coupling of the Northern and Southern Hemispheres.

Mr. GORE. Dr. Geiger?

Dr. GEIGER. I similarly, in view of all the scientific uncertainties and variables that we can only guess at, would say it is somewhere in between. But I think there is a pitfall, a danger, in a way, in the very question that Schell raises and that you're asking of us. The danger is somehow that we end up saying, "Gee, if there won't be the extinction of human life, then we must be OK and it won't be so bad after all because we are going to avoid the worst." It is not merely when we say the probability is somewhere in the middle. Again, prudence suggests that we accept that the probability is there and that we be prudent.

But, beyond that, to recognize that we are talking about—even if there continued to be survivors for generations—about a very different definition of survival and a very different kind of life, and the biggest imponderable is not the one that has to do with numbers but the one that has to do with a profoundly altered environment. We evolved in it. We are adapted to this environment. If we change that environment significantly, we can't make accurate estimates of recovery or survival or the like. That is a fact that goes well beyond however many million or billion people are killed in any given scenario.

Mr. GORE. Dr. Drell, did you want to add something to that point?

Dr. DRELL. No, no. I agree.

Mr. GORE. One of the concerns that has been raised is the question of blindness among animal species that don't wear little bitty sunglasses after a nuclear exchange. Other witnesses later will speak to this as well. But how do you evaluate that possibility, that the ozone depletion will be sufficient to cause blindness in all unprotected eyes, human and animal alike?

Dr. GEIGER. You are going to hear more expert testimony, as you have indicated. The most recent data that I have read suggests that it might take about a 50 percent depletion of the ozone layer to really make likely widespread blindness from ultraviolet radiation in unprotected humans or others, and that a 50-percent depletion is possible.

I would add only two things to that in advance of the testimony you are going to hear. Obviously, the uncertainty of that figure, that means it may be less than 50 percent as well as more than 50 percent that is required to do that. Secondly, not to make that same mistake again, as I was talking about, to recognize that even

if the 50 percent figure is the requirement, that levels less than that are not harmless, that they will be doing damage.

I think Dr. Drell and the others will agree, that the most difficult task of all, but probably the most dangerous possibility, is the cumulation of these marginal kinds of damage—a piece here, a bit there, a contribution from forest fires, a contribution from starvation, a contribution from epidemics. They are not only additive, but synergistic. They work with each other and make each other worse.

Just to add a point to that, there has really been insufficient demographic analysis of what happens in a given area, the northern hemisphere even, when you get down to 50 or 55 million people surviving and you have vastly increased the infant mortality rate and you have people living in a situation in which their futures, their children, will be dying at more rapid rates than before they do. We don't know very much about the dynamics of population survival in that situation, and it is there that these effects we're talking about today will have their greatest impact.

Dr. DRELL. Just two quick comments to add on to what Dr. Geiger said.

One of the elements of uncertainty is the sensitivity of the decrease of ozone, because of the nitric oxides rising into the stratosphere, to the size of the nuclear warhead being used. Larger warheads are thought to have a bigger effect, that is to put more nitric oxides into the stratosphere. This is thought to be perhaps less important an effect for smaller warheads. We are moving these days with our modern nuclear arsenals to smaller warheads in larger numbers. On this very little quantitative understanding exists right now.

But more important, to emphasize the theme of Dr. Geiger's remarks, we are a very delicately balanced set of organisms in the world and there is a very different sensitivity of different organisms to a changed level of ultraviolet radiation. So the balance, no matter how big the effect, the balance is going to be disturbed greatly. Little animals presumably are less vulnerable to destruction by ultraviolet radiation than are the big ones. And when you alter qualitatively the balance of life cycle, all bets are off, because we feed on each other.

Mr. GORE. Let me welcome to the subcommittee hearing Congressman Tom Downey of New York, who is an alumnus of this Science and Technology Committee and a well-known expert from the Armed Services Committee on many of these topics. He has now moved on to Ways and Means. But we appreciate his participation here today.

Mr. DOWNEY. Thank you, Al, and thanks for the recognition. I want to say hello to both Sidney and Jack who I have seen both on Ways and Means and on television programs.

I don't know if the subcommittee has covered it, but one of the scenarios that is routinely referred to is the "surgical strike", as though one can wage a nuclear war in a climate of precision and understanding, where the Russians attack our land-based missiles and we respond by attacking theirs.

I am curious to know—and I think, Dr. Drell, you referred to it in your statement—if this is possible, and two, what the consequences of a surgical attack would be on either side.

Dr. DRELL. Let me summarize very briefly what I said before you came, Congressman. I quoted Gen. Davey Jones, the retired Chairman of the Joint Chiefs of Staff, who said "I don't see much chance of a nuclear war being limited or protracted." I completely endorse that statement. It has to do with human nature. Once you have crossed the nuclear firebreak, because your vital interests are engaged, it seems very unlikely that human nature would operate in a way so that you wouldn't continually dig deeper into your nuclear arsenals of 50,000 weapons. And then I referred, as a technician, to the technical fact that the ability to limit a nuclear war through a command and control system, to my mind, is not at all established. We have worldwide dispersal of weapons. We would have delegation of nuclear use authority necessarily, given the time scale of missile flight. There is confusion and error in a war, we know that. The ability for a command and control system, which itself is threatened and may be damaged in a nuclear environment, to control a nuclear war, is an extrapolation I am not willing to make.

But, having said all that, one can go ahead and do the casualty calculations that I don't believe in about limited nuclear war and see what the consequences are. Perhaps one of the later witnesses, Dr. Von Hippel, will comment, because there was a study done by the Congressional Office of Technology Assessment in response to claims made by a previous Secretary of Defense that there were things like limited nuclear war scenarios in which we went after each other's missiles and fewer than a million casualties would result. Then when you looked into the assumptions, which we did for the OTA, you find that that was a terrifically elegant surgical scenario. It was so surgical that it didn't destroy the missile targets, either. And when you modified it—Whenever you use the word "surgical", I really hate using that word—

Dr. GEIGER. I was about to come to that. [Laughter.]

Dr. DRELL. I apologize. I won't use the word. But in these "limited strikes", if you added some ground bursts because you really wanted to destroy those hardened missile silos, then depending on the wind patterns, you were back up to 20 million casualties, even assuming the use of a civil defense system. So I think all bets are really off on that one.

Dr. GEIGER. Let me add, just very briefly, a medical, biological, and environmental comment to that.

I was about to say, although I am not a surgeon, I can't think of a way to give surgery a bad name than to keep calling these things surgical strikes.

But, in fact, there is a distortion in there of the same kind as the distortions I was talking about a little while ago. The connotation of surgical strike is not only that it will be carefully limited to one place, but that it will have no systemic effects, that the effects, both short term and particularly longer term, won't have any impact anywhere else and that you are not disrupting a system.

I can do, I guess, a surgical strike on my aorta at the level of my belly button, and it is going to have very serious consequences at distances quite considerable from my belly button because a system has been interrupted. You could call that a surgical strike if you want, but that is the distortion.

We are going to set loose, even in such so-called surgical strikes, environmental effects, ultraviolet effects, infectious disease effects and so on, that won't stay comfortably out there in the Montana missile fields or wherever, and that is what some people I think would like us to believe.

Mr. DOWNEY. Thank you very much.

Mr. GORE. Thank you.

We have a series of five votes of some significance on the floor right now. That process will probably take about 45 minutes. So I would ask the patience and indulgence of the next witnesses and our guests. I would like to ask more questions of you two, but in light of the circumstances—perhaps you could respond to some short questions for the record.

Our next panel will be Dr. Herbert Abrams, chairman of the Department of Radiology at Brigham and Women's Hospital in Boston, and Professor Donald Pitts with the College of Optometry at the University of Houston.

I would like to thank our first two witnesses and tell our next witnesses that we will reconvene at 11:45.

[Whereupon, the subcommittee was in recess.]

Mr. GORE. The subcommittee will come back to order.

I apologize for the inconvenience caused our guests today, but as I explained as the outset, it is one of those unusual days.

The two witnesses on this panel are Dr. Herbert L. Abrams, chairman of the Department of Radiology at Brigham and Women's Hospital in Boston, and Professor Donald G. Pitts, with the College of Optometry at the University of Houston in Texas.

We will begin, Dr. Abrams, with you. I might say that Dr. Abrams is not only a professor of radiology at Harvard medical school but national cochairman of the Physicians for Social Responsibility. The comments I made earlier to Dr. Geiger are certainly appropriate at this place in the record as well. It is awfully important work that you have done and are doing, and we are honored to have you here.

Your full text will be in the record at this point without objection and we will invite you to proceed as you see fit.

STATEMENTS OF HERBERT L. ABRAMS, M.D., PROFESSOR OF RADIOLOGY, HARVARD MEDICAL SCHOOL, AND CHAIRMAN OF RADIOLOGY, BRIGHAM AND WOMEN'S HOSPITAL, AND SIDNEY FARBER CANCER INSTITUTE, BOSTON, MASS., AND DONALD G. PITTS, PH. D., UNIVERSITY OF HOUSTON COLLEGE OF OPTOMETRY

Dr. ABRAMS. Thank you very much, Congressman Gore, members of the subcommittee, ladies and gentlemen.

Underlying the concerns of all of us here today is a sense of the complexity of this world and the remoteness of the decisionmaking processes that may radically affect the world and our conditions of life and survival and civilization. Civilization has been described as a race between education and catastrophe; the question is, who will win the race?

What I want to do now is to view a scenario in what we have all lost because a massive nuclear exchange has destroyed much of the

Soviet Union and the United States. We can then ask ourselves first what kind of symptoms we can anticipate in the survivors.

In the acute survivors, there are obviously the symptoms of blast and burn. In addition, if we look back at Hiroshima and Nagasaki and the radiation sickness that developed, nausea and vomiting were virtually immediate symptoms and accompanied by loss of appetite and diarrhea in over 35 percent. The white blood cell count dropped. Both frank hemorrhages and petechial bleeding were seen, as well as ulcers in the oropharynx. Note that antibiotics, blood plasma, and transfusions would have been very important if they had been available.

The drop in white count as an effect of the explosion is no different from that of a hydrogen bomb or a nuclear accident or, for that matter, therapeutic irradiation. There is relatively little change in the early period. This is a biphasic effect. The individual will feel relatively well, then the marrow gets depressed, and in the second phase if the dose has been large enough, the lethal effects of radiation are seen. The white count drops very sharply and increased sensitivity to infection then begins to be manifest.

If the dose is below 200 rads, the clinical course is not so serious. With 300 rads or more, hospitalization is almost invariably required; with 500 rads, in 94 percent the exposure is lethal.

If we think in terms of large doses, with high exposure, cerebral death occurs within 2 days. With moderate exposure, gastrointestinal, death within a week to 2 weeks; with lesser exposures, a bone marrow or a hematopoietic, death within 4 to 6 weeks.

The effects of burn, blast, and radiation have dominated the discussions of the postattack period. But in the intermediate term, and in the delayed period, after this acute attack, infection and the spread of communicable disease may represent the most important threat to survivors.

Let's take a look at that period. The United States that we will view has undergone a 6,500-megaton attack. The magnitude of such an attack, the so-called CRP-2B model which is used by FEMA, the Federal Emergency Management Agency, in civil defense planning, reflects the world of the eighties. It represents 524,000 Hiroshima bombs.

The targets of attack in order of priority will have been the military installations, military-supporting industrial transport logistic facilities, others of the basic industries, and then, of course, population concentrations of 50,000 or greater. Some 4,000 megatons will have been detonated on urban areas and population centers.

Moments after this surprise attack, 86 million in this country of a fully-exposed population, nearly 40 percent, will be dead. An additional 34 million, 27 percent, will be severely injured; 50 million additional fatalities will occur during the shelter period, for a total of 133 million deaths. And many of the millions of survivors will have experienced moderate to high radiation doses.

What, then, are the periods under consideration with regard to the medical problems? There is, first the barrage or immediate effect period; then the shelter period, for days or weeks following the attack, during which survivors attempt to sustain themselves in fallout shelters with intense radiation, fires, and deprivation.

The postshelter survival period follows, when fallout has reached a level during which people can get out of the shelters for minutes to hours, food and shelter must be found, the injured must be nursed, the dead buried, the debris cleared, the harvests reaped, and possibly the next harvest sown. The long-term effects period follows. In this primitive and hazardous environment, survival is the only coherent goal.

During the long-term effect period we can assume that survival has been accomplished by some and a recovery of sorts initiated. A societal structure may be emerging. Some food supplies may have been secured, shelter obtained, perhaps even communities established. A primitive social organism now faces all of the problems of underdeveloped countries. The long-term effects of the attack then become apparent.

The problem of infection, however, must be addressed, during the shelter period, and more particularly during the postshelter survival. Why is infection likely to be so dangerous? There are many factors—radiation, trauma and burn, starvation and malnutrition, exposure and hardship—all of these increase the sensitivity to infection.

Radiation does so because of a decreased antibody response, the decreased effectiveness of cellular defense mechanisms, the decreased effectiveness of immunizing agents, and increased susceptibility to some toxins, so that vaccination will be far less effective.

Radiation has a major effect on the mucosa of the intestine, and the ulcerated mucosa provides a portal of entry for gram-negative organisms that are frequently lethal. Bacteremia may occur. Note that susceptibility to infection is directly related in degree and duration to dose of radiation, and that increased susceptibility extends not days, not weeks, but many months thereafter.

There is also—and I think it is important to emphasize—a synergy between the effects of burn and radiation, and many will suffer from both. Here, with 100 rads of radiation there is zero mortality; with burns, only 12 percent mortality; with burns plus 100 rads, 75-percent mortality. These are the circumstances of that intermediate period.

Note also that with burns and radiation and no antibiotics there is a 75-percent mortality. But if antibiotics were available in that period, then one might anticipate that there could be some control of this high lethality of the combination of the two.

During this period food will take on an immense value. Persons or regions with food supplies may well be reluctant to relinquish their holdings. On shelter emergence, most of the food stores will be destroyed in urban areas.

One source that might remain available is grain stored on and off farms in small towns and rural areas. During the immediate postshelter period, obtaining, transporting and distributing grain to hungry survivors will be the most important survival activities. But these efforts will be hampered by the negative correlation between population and grain density.

Fuel shortages will constitute an enormous problem. It has been emphasized that as much as 99 percent of U.S. refining capacity could be destroyed, and that this would clearly impede the trans-

port from the food-rich centers to the population centers of this country.

Malnutrition lowers physiological resistance to disease and it heightens susceptibility to pathogenic organisms. A regressive subsistence loop would develop. Malnutrition, producing either death or more disease or possibly, because of weakness, decreased economic and agricultural production, and then a vicious cycle that eradicates the will to recover and reconstruct.

There are other factors. Dehydration. Remember, you need about a gallon of water a day if you're in the hot environment of a fallout shelter. The incidence of diarrhea and vomiting would be very high among survivors. No water is normally stored in public fallout shelters, no means by which to transport or store it necessarily available.

Beyond that, the matter of exposure and hardship require consideration. We know of the widespread destruction of urban housing that will occur. In Hiroshima and Nagasaki, huge residential areas were totally obliterated.

Heating fuel will become unavailable. General hardship accompanied by the need for intensive labor, with exhaustion, fatigue and poor nutrition, will promote great vulnerability to infection.

Surviving Americans would for the first time experience the underdeveloped world as their natural habitat.

Let me take you back to the early 19th century. In 1804, among the 10 leading causes of death, infection predominated. Consumption, convulsions, cholera, inflammation of the chest, more infection, croup, small pox, typhus, and typhoid. That was 1804 in the United States.

In 1945, the world has changed. And the top of the list is heart disease; then cancer, accidents, cerebral hemorrhage. Infection has assumed a much less significant place in the list. What we can anticipate is a regression to the first kind, the underdeveloped world type of killers. The successful campaigns to eliminate the lethal epidemics such as cholera and typhoid have been accompanied by a failure to develop resistance to these diseases.

There are other factors as well—the lack of antibiotics, drugs, plasma, a shortage of physicians, nurses and hospital beds, easy spread and crowded quarters. And what of these crowded quarters?

If you go back to the time of the Civil War and look at Confederate prisoners of war, in those crowded conditions it was infection that was the great killer of the period. In the postattack period, respiratory and GI infections may spread very rapidly. The mortality rate will be sharply increased.

The familiar barriers to communicable disease spread are sanitary, water supply, properly prepared and refrigerated foods, sewage treatment, waste disposal. These will all be seriously compromised. And in their absence we can expect a host of enteric diseases not yet experienced by most Americans to spread widely—hepatitis, coli infections, salmonella and amoebiasis.

Remember that insects are generally more resistant to radiation than man. This fact, and the prevalence of corpses, waste and untreated sewage, the depletion of birds as predators, and the destruction of insecticide stocks would engender a huge increase in insect growth. This, combined with the failure to provide adequate sanita-

tion, might sharply limit the capacity to control such diseases as typhus, malaria, et cetera.

Now, there will be millions of corpses left in the wake of a nuclear attack. They could constitute a serious disease threat. With transportation destroyed, weakened survivors, and a multiplicity of postshelter reconstruction tasks, the disposal of corpses will be remarkably complicated. In order to bury the dead, an area four times as large as the city of Seattle would be required for the cemetery.

When we look at factors limiting the response to infection, we must emphasize that coherent efforts to control and limit the spread of disease require surviving government, organized geographic units, communication networks, and a survival situation in which physicians and health officials are able to perform their tasks.

All of the health countermeasures depend upon the involvement of physicians and health workers. Casualties among doctors will approximate 80 percent. Uninjured physicians will have 32 million injured to treat.

Hospital beds will be widely destroyed. The compared ratio of patient to hospital bed before, 1 to 1, must be compared to the post-attack ratio of 17 to 1; of doctors to patients, 4 to 1 before attack, and 97 to 1 ranging up to 150 to 1 afterward.

There will be many millions of burns. In the United States today, we have 1,300 burn beds available. There will be literally millions who require ICU beds. In this country today we have 47,000 ICU beds. Not only that, but with the destruction that will occur, there will be virtually no burn beds available and very few ICU beds available after the attack.

Antibiotics are not effective in combating most viral disease, but beyond that, there are several dangerous bacterial diseases like diphtheria and tetanus which respond poorly. Remember that a massive nuclear attack would virtually eliminate the pharmaceutical industry which is concentrated in the Northeast of the country.

Studies performed in the late sixties identified 23 diseases that might be significant. There are two categories that are potentially very important. There are the classic epidemic diseases, fortunately of low incidence. But beyond that, there are serious existing diseases which have relatively low mortality today but which could be expected to spread widely, and respiratory diseases are among those which will particularly be major killers among the old and the young.

Mr. GORE. Dr. Abrams, again I have to apologize and interrupt you at that point. We have a vote on the floor.

Congressman Shamansky is running a relay race and will be back momentarily to reconvene the hearing. But Congressman Walker and I are going to have to go to this significant vote.

So we will reconvene in approximately 5 minutes, maybe even less, when Congressman Shamansky gets back.

[Whereupon, the subcommittee was in recess.]

Mr. SHAMANSKY [presiding]. Dr. Abrams, would you be kind enough to resume your testimony.

Dr. ABRAMS. We were talking really about the two categories of disease, the conventional epidemics, and then these serious existing

diseases that can confidently be expected to spread in this period of altered immunity and increased susceptibility and, as well, with the conditions of malnutrition and deprivation and hardship.

I want also to emphasize that there are diseases that we no longer think of as important ones in this modern world, and yet, in fact, we are going to have to think of them once again.

One of these is plague. No one considers that as a significant threat to American society. It depends basically on two vectors, the rat and the flea, and these may either be wild or domestic rats, and yet carry the disease to man by flea bite or by contact. I think all of us know that in the 16th and 17th centuries large urban plague epidemics were seen throughout Europe. What we don't realize is that in the 20th century there have been over 13 million deaths from plague around the world, and that interestingly some of these were in the United States, a relatively small percentage. I might add that just recently 45 cases were reported from the State of New Mexico in the annals of internal medicine.

If you consider the rat population of the country, you should understand that *pasteurella pestis*, the organism that causes plague, is widely distributed in the 14 Western States. The organism lives in an easy ambience or relationship with the rat. The rat is not infected, but the rat can transmit it. The important point about all of this is that precisely those conditions of devastation or wartime will be set up in this postnuclear war period when that organism may flourish in the rat. The rat now has an altered immunity, but its immunity is not as radically affected as man because it has its own underground shelter system. So you have these two vectors of disease and then you have man whose resistance is diminished. That, of course, will be a major concern. Plague may become one of the most serious of the postattack problems.

The disease has been endemic in the Western States.

Here you see its incidence up until 1951. In California the mortality rate of those cases that occurred was 70 percent, as it was in Florida.

Tuberculosis. We all think we have conquered tuberculosis. Those of us in the greater urban hospitals are now beginning to see more and more of it once more.

Its death rate rises strikingly with overcrowding. In the United States we have 35 million individuals with a positive tuberculin test. It is mostly in the older age group—those most susceptible to pulmonary infection in general, and to dehydration—that the positive tuberculin test has its greatest prevalence.

The death rate for tuberculosis increases strikingly in times of war. That is not just due to crowding.

The mortality rate of tuberculosis goes up when animal protein intake or meat intake is down. That is what we will confront in that postnuclear war period, a period in which caloric intake is drastically reduced and a reciprocal relationship between lethality and protein intake exists.

In the aggregate, death from communicable disease among survivors may approach 20 to 25 to 30 percent, and enteric and respiratory diseases represent major threats to survival.

It is fascinating that in a computer simulation of the effects of a single nuclear explosion 9 miles south of New Orleans, it was cal-

culated that 35 percent of the survivors died from infectious disease in the first year postattack. This, of course, would be in addition to some of those dying, the wounded, from blast, from burn, and from radiation.

Just for purposes of comparison, let me say that the expected deaths from noncommunicable disease such as heart disease or diabetes is estimated to be between 2.5 and 3 percent of the survivors. So, though no existing data prove that catastrophic epidemics will occur, the matter is one of overwhelming importance and uncertainty. What we know is that infection will be a huge threat and that the resources to grapple with this threat will be minimal, indeed.

The other long-term effects I can deal with really only in rather sketchy fashion. Hyperthyroidism and thyroid tumors, have now been demonstrated. With prenatal exposure, women in Hiroshima exposed had a marked increase in stillborns. The mortality of children in the first year of life increased markedly. Among the survivors there was increased mental retardation, there were defects of the skeleton and of the eyes, and a marked increase in induction of tumors, particularly the incidence of leukemia in the fetuses exposed during the Hiroshima and the Nagasaki attacks. The genetic effects demonstrated so clearly in animals, have only recently begun to be documented in the survivors of Hiroshima and Nagasaki.

Finally, the cancer incidence. The risk factors are very striking, indeed. It has been estimated that from the tests done thus far—remember, there were 1,270 nuclear tests, of which 550 have been in the atmosphere. From these tests, the best estimates suggest that there have been 100,000 additional deaths from cancer alone, and perhaps one-half of that due to genetic defects.

Now, the nuclides of greatest concern are strontium, which has a half-life of 29 years, and cesium, with a half-life of 30 years. These have huge, very high fission yields. The strontium goes to man from the soil, from plants and animals, especially milk and meat, and the cesium from fish, vegetables, and other plants.

We can also consider some of the data on cancer from Hiroshima and Nagasaki, which demonstrate the increased incidence of leukemia, and of the solid cancers.

Rather interestingly, leukemia occurs within a period of about 4 to 5 years afterward in strikingly increased incidence. We knew up until recently that breast cancer, thyroid and lung cancer had an increased incidence, and now it is absolutely clear that cancer of the esophagus, stomach, and urinary organs, as well as the lymphomas, must be included among the tumors caused by this series of explosions.

So if we ask ourselves the question—and it was asked earlier in this session—is survival possible, the answer is yes. If we pursue that question further and attempt to define the nature of survival, my belief is that it is difficult to relate to our life as we know it in the United States today. For many, it may well be that they would have preferred to join the scores of millions who died. For others, life may be tolerable in its physical aspects, but the immense psychological burden of death and devastation and family disintegration might be very difficult, indeed, to bear.

Now, a few concluding comments. Doctors have never, to my knowledge, been involved in an antiwar movement because they have always observed that war, as an extension of national policy, has characterized the behavior of man over the centuries, and yet society has been able to emerge intact. But physicians have never before been faced with such a life and health threatening possibility, nor with a clear sense that the planet could be so changed.

On different sides of the globe, the American Medical Association—and remember, that doctors are a very conservative constituency—and the Soviet Academy of Medicine issue the same warnings. I can say to you that we can tell you how to set a broken bone, but we can't repair a massive brain injury. We can tell you how to sew up a ruptured liver, but we can't treat a patient in shock unless there is blood or plasma substitutes. We can tell you about radiation effects, as I have, and radiation sickness, but we cannot treat a man exposed to 5,000 rads because we know we will have a brain death in hours to days.

We have great skills in treating burns, but in this country, with 1,300 burn beds, the millions of burn patients in a nuclear holocaust would have no place to go. In brief, we know that there is no credible response to a massive nuclear war.

Finally, physicians are not politicians. We are not experts in arms or arms control. We are not diplomats or negotiators or legislators. We are simply doctors. We are concerned about this greatest threat to life and health of the century, and we feel a professional and humane obligation first to become involved, and second, to warn you and really the world, much as we would like to help in the time of sickness and disease and injury and radiation exposure, we simply won't be here. We'll be dead, like the nurses and other health workers, and our hospitals will be destroyed just like your homes and your schools. My own judgment is that this battle is no longer really between the great nations. It is between devastation and survival, and the enemies are these weapons of annihilation.

Thank you.

[The prepared statement of Dr. Abrams follows:]

IN THE AFTERMATH: MEDICAL PROBLEMS OF SURVIVORS

Herbert L. Abrams, M.D.*

The terrible military machine. . . must be in continual motion, grinding up human lives . . . it must be fed upon new fields of slaughter, pillage and devastation.

Winston Churchill, Describing Hitler's Germany on June 22, 1941

I refuse to accept the cynical notion that nation after nation must spiral down a militaristic stairway into the Hell of nuclear destruction.

Martin Luther King, 1964

The devastation and chaos that would follow an all-out nuclear war and the potential for regression to a social structure unknown to Western man have been appropriately emphasized. But the nature of the medical problems that will confront survivors has not been widely conveyed. The effects of burn, blast, and radiation have dominated the discussions of the postattack period. In the intermediate term, however, infection and the spread of communicable disease represent the most important threat to survivors.

In depicting a massive nuclear exchange, we will assume that the United States has undergone a 6500 megaton attack, the so called CRP-2B model used by the Federal Emergency Management Agency in civil defense planning. In terms of yield, it represents 524,000 Hiroshima bombs. The targets of attack, in order of priority, will have included:

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- 1) military installations
- 2) military-supporting industrial, transport, and logistic facilities
- 3) other basic industries and facilities which contribute to the maintenance of the economy
- 4) population concentrations of 50,000 or greater

Some 4000 megatons will have been detonated on urban areas and population centers.

Moments after the attack, 86 million - nearly forty per cent of the population - will be dead (Table 1). An additional 34 million - twenty-seven per cent of the survivors - will be severely injured. Fifty million additional fatalities are anticipated during the shelter period, for a total of 133 million deaths. Many of the millions of surviving injured will have experienced moderate to high radiation doses, and will have residual blast and burn injuries.

The periods under consideration (Table 2) are as follows:

Immediate effects. During the barrage period, the explosions almost instantaneously inflict millions of lethal and non-lethal blast, thermal and immediate radiation injuries on those caught in and around the blast areas.

Shelter period. From the time of the attack to days or weeks later, those surviving the initial explosion attempt to sustain themselves in fallout shelters, amid intense radiation, fires and deprivation.

Post-shelter survival. Fallout has reached an "acceptable" level for emergence for variable times. The problems of obtaining food, developing independent shelter, and recovering from the acute injury must be confronted. The injured must be nursed, the dead buried, debris cleared, the harvest reaped, and the next harvest sown. In a primitive and hazardous environment, survival is the only coherent goal.

Long-term effects. Survival has been accomplished and some kind of recovery initiated. A societal structure is emerging, food supplies have been secured, shelter obtained, and communities established. A primitive social organism, with potentially intense regional and intra-regional competition for food supplies, faces all of the problems of underdeveloped countries. During the early years, the first cases of radiation-induced leukemia appear: later the solid

cancers will develop in the lungs, thyroid, breast and colon.

The problem of infection and communicable disease must be addressed during the shelter period and more particularly during the post-shelter survival period. It requires careful consideration not alone because of its human cost, but also because of its potential impact on the recovery process.

What, then, is the nature of the threat: Why is the likelihood of infection so much greater in the postattack world?

Bases for Increased Risk and Severity of Infection

Most survivors will experience increased susceptibility to infection both because of the pervasive direct effects of nuclear weapons and the subsequent pressures and hardships confronted. Several factors will be of special importance.

1. Radiation

Radiation affects the immune system in a number of different ways, not least of which is its capacity to injure the bone marrow and the lymph nodes. Hematologic changes may occur with doses as low as 50 rems. The following changes occur:

- 1) decreased antibody response
- 2) decreased effectiveness of cellular defense mechanisms
- 3) decreased effectiveness of immunizing agents
- 4) increased susceptibility to some toxins

Thus, vaccination will be less effective.

Radiation also has a major effect on the lining or mucous membrane of the intestine. The ulcerated mucosa provides a portal of entry for intestinal bacteria into the bloodstream, with bloodstream infection a certain sequel. These organisms are frequently difficult to control with antibiotics.

Twenty-three million survivors of a large scale nuclear war will suffer from radiation sickness, implying a mean dose of 200 rems or more.* But the number of cases with

* Four hundred and fifty rems total body irradiation is considered the dose that will kill 50% of exposed humans. The "rem" is the unit that measures the absorbed dose of radiation in tissue.

doses between 100-200 rems will probably equal that number, so that 50 per cent of the population might have lowered resistance to disease from radiation exposure alone, extending over a period of many months (Figure 1).

2. Trauma and Burn Casualties

Among the millions suffering from trauma and/or burns, over a third will also suffer radiation sickness. Aside from the risk of infection related to the open wounds, weakness and incapacitation may be expected to increase their general vulnerability. There is also a known synergy between burns and radiation that profoundly increases the mortality rate.

3. Malnutrition and Starvation

During the shelter period, available quantities of food would vary. Adults can maintain health for several weeks with only minimal amounts of nutrition. In some locales, fallout might prevent emergence from shelters to a point where health would deteriorate. Infants and young children, in particular, might experience severe malnutrition due to insufficient or inappropriate foods during an extended shelter stay.

During the post-shelter phase, three crucial periods can be defined: shelter emergence until the first harvest, first harvest until the next harvest, and all subsequent seasons. The first two periods depend a great deal on the time of the attack during the year, and the third depends on post-attack recovery and environmental conditions. Upon shelter emergence, most of the food stores will be destroyed in urban areas; other supplies will most likely be consumed during or soon after the shelter period.

The essential supply of food that may be available will be the grain stored on and off farms in small towns and rural areas. Upon this supply would depend the lives of millions of survivors until the next harvest was available.

The amount of stored grain varies considerably during the course of the year. Supply for the surviving population might vary from 200 to 500 days, with great dependence on the next harvest.

But food piled high in silos in remote regions will do little good for a hungry populace. Grain must be obtained, transported, and distributed to the survivors where they are located. Grain transportation will be the most important survival activity in the immediate post-shelter period.

This problem will be made much more difficult by the negative correlation that exists in the United States between population and grain density (Figures 2 & 3).

Furthermore, assuming that trucks and highways will be usable, an essential commodity for the transportation of grain is fuel. It is estimated that as much as 99 per cent of U.S. refining capacity could be destroyed.

4. Exposure and Hardship

Widespread destruction of urban housing will occur, with major damage to rural housing as well. Heating fuel may be unavailable. General hardship will be accompanied by the need for intensive labor, with exhaustion, fatigue, and poor nutrition promoting great vulnerability to infection.

5. Lowered Natural Resistance to Disease

Surviving Americans would for the first time experience the underdeveloped world as their natural habitat. Unlike the population of impoverished lands, however Americans do not have the high natural immunity to a host of dangerous diseases that allows many in the Third World to survive. The omnipresence of antibiotics has clearly altered the

normal production of antibodies to infectious agents among the developed nations. With potential destruction of the pharmaceutical industry, as well as post-attack disorganization and chaos, antibiotics will be in short supply for countries that have depended on them.

The successful campaigns to eliminate the lethal epidemics such as cholera and typhoid fever, have been accompanied by a failure to develop resistance to these diseases. Reintroduction of such "exotic" diseases might find the population incapable of handling them, as were American Indians exposed to diseases of Europeans.

Measles, whooping cough and diphtheria may be rampant in un-immunized infants, and beta hemolytic streptococcal infections will be widespread.

Factors Increasing the Spread of Disease

1. Shelter Conditions

Large public shelters may operate under severe space limitations, with thousands packed into inadequate areas. Under these circumstances, hepatitis and respiratory and gastrointestinal infections may spread rapidly. Most shelters will lack adequate forced ventilation. When ventilation systems are present, the blowers and fans could

easily be rendered inoperable by an overpressure of 1 PSI and the systems blocked by electric power failure. Heat and humidity in the shelter would then increase and the absence of a continuous flow of fresh air would encourage the spread of infective micro-organisms.

The length of time that fallout radiation will enforce basement and underground occupancy will be an important determinant of disease spread. This period may well be one week to several months. Those in highly radioactive cities will have much longer stays and may have significant exposures even in shelters, ~~(shelters)~~. After it is permissible to work outside, it may still be necessary to eat, sleep, and rest in the fallout shelters.

2. Sanitation

The barriers to communicable disease spread accomplished today by a sanitary water supply, properly prepared and refrigerated food, sewage treatment, and waste disposal will be seriously compromised in the post-attack environment.

With impure water, contaminated food, and general unsanitary conditions, a host of enteric diseases not yet experienced by most Americans may be expected to spread widely. These include infectious hepatitis, e coli,

salmonella, shigella, amebic dysentery, and possibly typhoid and paratyphoid.

3. Insects

Insects are generally more resistant to radiation than man. This fact, and the existence of corpses, waste, lack of sewage treatment, depletion of avian predators, and destruction of insecticide stocks and production would engender a huge increase in insect growth.

The absence of control of insect growth, combined with failure to provide adequate sanitation, might sharply limit the capacity to control such diseases as typhus and dengue fever.

4. Corpses

The health problem created by millions of corpses post-attack may represent a serious disease threat. In many areas radiation levels will be so high that corpses will remain untouched for weeks on end. With transportation destroyed, weakened survivors, and a multiplicity of post-shelter reconstruction tasks to be performed, corpse disposal will be remarkably complicated. In order to bury the dead, an area 5.7 times as large as the city of Seattle would be required for the cemetery.

Factors Limiting the Response to Infection

1. Government Organization

The United States has developed an extraordinary ability to take effective countermeasures against communicable diseases. Should an outbreak occur, a public health network will be informed, the rest of the country alerted, and appropriate steps taken. In 1947 a man infected with smallpox mingled with New York City crowds for several days. More than 6,350,000 were immediately vaccinated; as a result, only 12 additional cases appeared. More recently, the unfortunate Swine Flu episode illustrated how the hint of an epidemic could bring enormous medical resources to bear upon the threat.

Coherent efforts to control and limit the spread of disease require a modicum of surviving government, organized geographic units, communication networks, and a favorable enough survival situation so that physicians and health officials can perform their tasks.

All of these conditions are speculative in the post-attack world. Most radio contact will be eliminated by nuclear weapons effects. Treating the wounded will require the full attention of available medical resources. For a sustained period, surviving officials may have to remain in

shelters, and food and water may be their primary concern. The huge number of injured, the tenuous food situation, massive industrial destruction, enormous debris removal and body disposal tasks, and disparity between "food rich" and food poor regions will seriously undermine inter-regional cooperation.

2. Disease Detection, Diagnosis and Treatment

Health countermeasures against potential epidemics depend upon the involvement of physicians. Casualties among physicians and other health personnel will approximate 80%. This is higher than the casualty percentage of the population as a whole (73%) because physicians are disproportionately represented in the large cities. Government estimates suggest that there may be 79,000 uninjured physicians surviving a large-scale attack (Figure 4). They will have 32 million injured to treat of whom 18 million suffer from radiation sickness and 14 million from trauma and/or burns. If only the trauma and burn victims are included, this represents a ratio of 175 injured for every uninjured physician. Furthermore, most hospital beds will be destroyed (Figure 4). Moreover, physicians will be confined to shelters for many days or weeks. If we assume that the average shelter contains 100 people, and no more than one physician is in any shelter, only one in 12 shelters will have an uninjured physician. If there should

be a serious epidemic, it will affect physicians as well. More physicians would become incapacitated as the number of sick increased, further raising the injured to physician ratio.

Laboratories are essential for dealing with communicable disease, but they will be highly vulnerable to the effects of an attack.

The prompt detection and diagnosis of communicable diseases essential to identification of medical resources needs will thus be severely impeded during a crucial period.

3. Inadequacy of Countermeasures

Many of the countermeasures required for enteric and vectorborne diseases will be unavailable in the disorganization of the post-attack period. Their control involves assuring supplies of pure water and uncontaminated food, disposal of sewage and waste, and removal of breeding areas for insects and rodents (Table 3). Both antibiotics and immunization would play an essential role in stemming epidemics.

But how effective would they be?

A. Antibiotics

Antibiotics are ineffective in combatting viral disease and cannot limit the spread of such infections as smallpox, viral gastroenteritis, and influenza. Several dangerous bacterial diseases such as diphtheria and tetanus respond poorly to antibiotics. Furthermore, the demand for antibiotics will be large. If laboratory tests are not available, they will be prescribed for all undiagnosed ailments. Stores of antibiotics will be largely destroyed in urban centers, and those still intact may be inaccessible for days or weeks because of intense fallout radiation. The pharmaceutical industry would be "virtually eliminated" in a massive attack.

B. Immunization

For several hazardous diseases, such as tetanus, poliomyelitis, measles, whooping cough, and typhus, immunization is the only effective direct means of control. In post-attack conditions, however, the effectiveness of vaccination programs will be diminished by the impact of radiation on the immune system. Millions who have had substantial radiation doses and will therefore need immunization most of all will benefit least.

Potential Pathogens in the Post Attack World

Studies performed in the late sixties identified 23 diseases that might be significant in the post-attack environment (Table 4). Many of these are encountered in endemic form throughout the country. Among them, potential epidemic sources may be divided into two categories. The first includes the classic epidemic diseases, fortunately of low incidence: The second, diseases of heightened incidence, but low mortality (Table 5). Respiratory diseases, including viral pneumonias, influenza, pneumococcus and streptococcus infections, and tuberculosis will particularly affect those living in crowded blast or fallout shelters, with an augmented impact on the young and the old. The diarrheal diseases such as Salmonella, Shigella, Campylobacter, and viral gastroenteritis, will be widely prevalent. Although their mortality rate is usually low, in the presence of radiation injury to the gastrointestinal tract it will be substantially increased. Furthermore, these diseases, as well as infectious hepatitis, may spread rapidly in the absence of adequate sewage disposal, pasteurized milk, or appropriate sanitary precautions. The group of diseases endemic to rural sections, and thus a danger to evacuated populations, includes rabies, plague, and tetanus. A number of other diseases such as cholera or influenza might spread rapidly in devastated areas.

A more detailed view of two among many diseases that are generally considered well controlled in Western society will indicate the roots of the concern for the role of communicable disease in the transformed post-nuclear world.

Tuberculosis

Tuberculosis, the Great White Plague of the 19th Century, was a lethal infection for large segments of the population. Death rates ranged as high as 550/100,000 in New York City. If the annual U.S. death rate of 184.7/100,000 from tuberculosis in 1900-1904 characterized our present population of 225 million, all the U.S. deaths from World Wars I and II, Korea, and Vietnam would be surpassed on one year and 10 days.

Should this concern us for the post-attack period, when we know that the mortality rate of tuberculosis has fallen below 1/200th of the 1900-1904 figures? In 1978 there were only 2,830 deaths, and 28,521 new active cases in the U.S. The percentage of the population who are positive reactors has also dropped dramatically to 4-8% of all tested.

But the bulk of this decline was achieved without the aid of drug therapy. By 1944, when the modern era of effective anti-tuberculosis drug treatment began, the mortality rate had dropped to 43.3/100,000, less than 24% of

its 1900-1904 rate. This change was largely attributable to improved socio-economic circumstances, particularly since the incidence and mortality of tuberculosis rose and fell frequently in the past with altered societal conditions, especially in times of war (Figure 5).

In World War I, mortality increased 218 per cent in Warsaw, reaching a rate of 974/100,000 in 1917. The highest incidence in all European cities in World War I was in Belgrade; the rate in 1917 reached 1483/100,000. This represented almost 1.5% of the population dying from tuberculosis per annum. During World War II, the death rate rose 268% in Berlin, 222% in Warsaw, and 134% in Vienna. An analysis of 2,267 chest reontgenograms at the Dachau concentration camp at the time of liberation showed that 28% had evidence of tuberculosis, of which nearly 40% was "far advanced."

All of the factors that would increase the susceptibility to and spread of infection in general would be particularly applicable to tuberculosis. The destruction of housing, lack of fuel, shortages of food, medicine and clothing, and sustained period of labor and struggle would create precisely the setting in which tuberculosis has flourished in the past.

Nutritional status has been traditionally associated with increased incidence and mortality from tuberculosis. Over 20 different studies have shown the relationship between food quality and tuberculosis, most striking during wartime. Animal protein is particularly important (Figure 6).

Fewer Americans have been exposed to tuberculosis today than ever before. There are numerous examples of catastrophic epidemics among largely unexposed populations. South African troops had a rate of 1745/100,000 from tuberculosis, while British troops had a rate of only 11/100,000. When Saskatchewan Indians were removed from nomadic to reservation life around 1880, their death rate from tuberculosis reached 9000/100,000.

The comparison with the underdeveloped world is an apt one, as a look at U.S. mortality figures of the past indicate. From 1804-1808, eight of the top ten causes of death were infections (tuberculosis No. 1), accounting for 1526 deaths annually per 100,000 of population. From 1900-1904, six of the top ten causes of death were infections (tuberculosis No. 2), with 964 deaths per 100,000. By 1945-1949, only four of the top ten were infections (tuberculosis No. 7) accounting for 154 deaths per 100,000, just 10% of the deaths resulting from infection 140 years before.

Plague

Plague has been a known source of epidemics for the past 3,500 years. In the 20th century alone, over twelve million deaths have been attributed to it.

Plague is endemic among wild rats in the 11 westernmost states. Over 30 types of wild rodents and rabbits have been found infected. Cats and dogs can also be infected both experimentally and naturally, or when they ingest infected rodents. Human contact with wild rodents is almost exclusively the source of plague cases in the United States.

A nuclear attack would create almost ideal conditions for breaching the "thin protective wall" against plague. Large areas of the Western U.S. now relatively devoid of inhabitants may receive an influx of refugees from threatened or devastated urban areas. Relocation plans call for enormous increases in the population of many remote regions. Humboldt County, California, for example, would experience a five-fold or more increase in population. Millions of urban refugees, unable to obtain shelter in existing dwellings, will build earth-covered "expedient" shelters in undeveloped areas. Such shelters might provide good fallout protection, but they would surely create ideal conditions for transmission of plague from rats.

Rodents are relatively resistant to plague, develop chronic infections, and may act as a reservoir for the disease. Radiation would increase their susceptibility, as well as that of man. High mortality among wild rodents would then help spread the disease to nearby humans. As the rodents die, the more resistant fleas would leave them and search for another host, such as man.

Once radiation has subsided in leveled cities, many will head back to reclaim whatever possessions may be found and to reunite with family members. Over 90% of the housing will be destroyed in a nuclear attack, and crowding in surviving buildings may be anticipated. Conditions in the damaged cities will continue to be favorable for the spread and propagation of plague. The rat population will increase because harborage and food for rats will be available.

A major danger comes not alone from bubonic plague transmitted by domestic rats, but from man-to-man pneumonic plague. Under post-attack conditions, radiation and stress will raise the conversion rate of bubonic to pneumonic plague to 25 per cent.

Quantitative Estimates of Infection
In the Post-Attack Period

In the aggregate, deaths from communicable diseases among the survivors may approach 20-25%. Estimates of both the incidence and the mortality of infection in the post-attack world would vary widely for different diseases.

In a computer simulation of the effects of a single nuclear explosion 9 miles south of New Orleans, it was calculated that 35% of the survivors died from infectious diseases in the first year post-attack in the absence of medical countermeasures. This high mortality from communicable diseases may be compared to the expected deaths from non-communicable diseases such as heart disease, diabetes, etc., approximately 2.5-3% of the survivors. Equally, it far surpasses the threat of cancer mortality, estimated at a few per cent or less of the survivors.

There are, therefore, numerous factors that point to an increased risk of serious epidemics in the post-attack environment. These factors include the effect of irradiation, malnutrition, and exposure on susceptibility; of unsanitary conditions, lengthy shelter stays, and insect population growth on the transmittal of disease; and of depleted antibiotic stocks, physician shortages, laboratory

destruction, and post-attack disorganization on the effectiveness of countermeasures.

While no existing data prove that "catastrophic" epidemics will occur in the post-attack period, the matter is one of overwhelming importance and uncertainty. What is certain is that infection will pose a substantial threat to health and recovery for all those injured by blast, heat, and radiation, and that the resources to grapple with this threat will be inadequate even for the un-injured.

Addendum: Delayed Effects

If we do survive, the most important delayed effects have to do with the induction of malignant disease. The carcinogenic effect of ionizing radiation with respect to leukemia, breast cancer, thyroid and lung cancer has been established; cancer of the esophagus, stomach and urinary organs, as well as the lymphomas, must be included among the tumors caused by the 1945 atomic explosion. The effect was highest among those under the age of 10 at the time of the bomb.

Anomalies in the foetus whose mother has been exposed and long-term genetic effects are problems of later generations.

References:

Abrams HL, Von Kaenel WE: Medical problems of survivors of nuclear war: Infection and the spread of communicable disease. N Engl J Med 305:1226-1232, 1981.

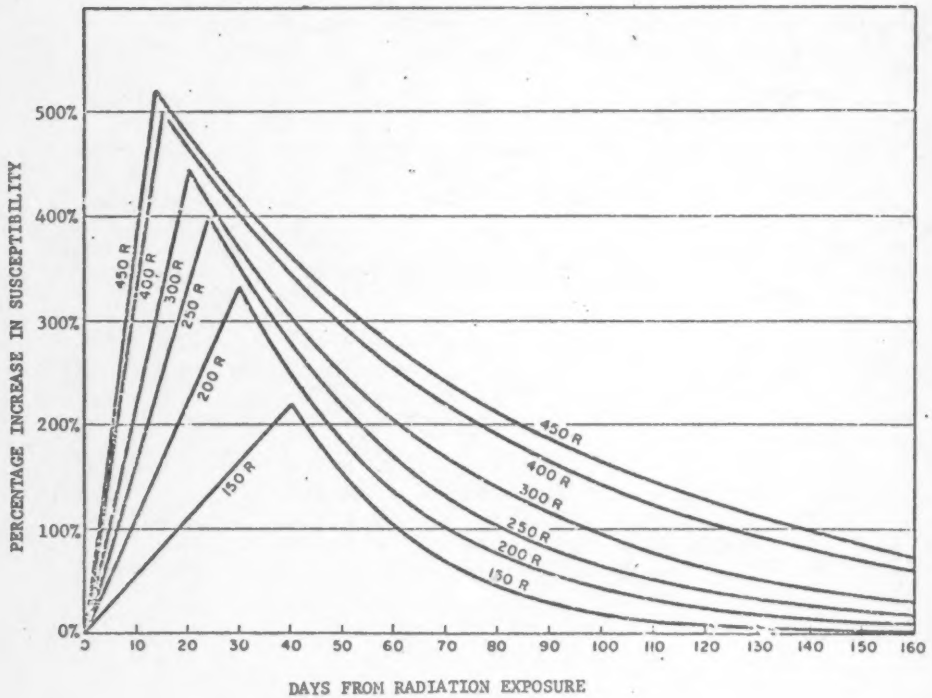
Glasstone S, Dolan PH, eds. The effects of nuclear weapons. Washington, D.C.: United States Department of Defense and United States Department of Energy, 1977:586.

Haaland CM, Chester CV, Wigner EP. Survival of the relocated population of the U.S. after a nuclear attack. Springfield, Va.: National Technical Information Service, 1976:20-1. (Defense Civil Preparedness Agency report no. ORNL-5041).

Mitchell HH. Plague in the United States: an assessment of its significance as a problem following a thermonuclear war. Santa Monica, CA: Rand Corporation, 1966. (United States Atomic Energy Commission report no. RM-4868-TAB).

Sullivan RJ, Guthe K, Thoms WH, Adelman FL. Survival during the first year after a nuclear attack. Washington, D.C.: Defense Civil Preparedness Agency, 1979:140. (Federal Emergency Management Agency report no. SPC-488).

FIGURE 1
EFFECT OF RADIATION EXPOSURE ON DISEASE SUSCEPTIBILITY OVER TIME



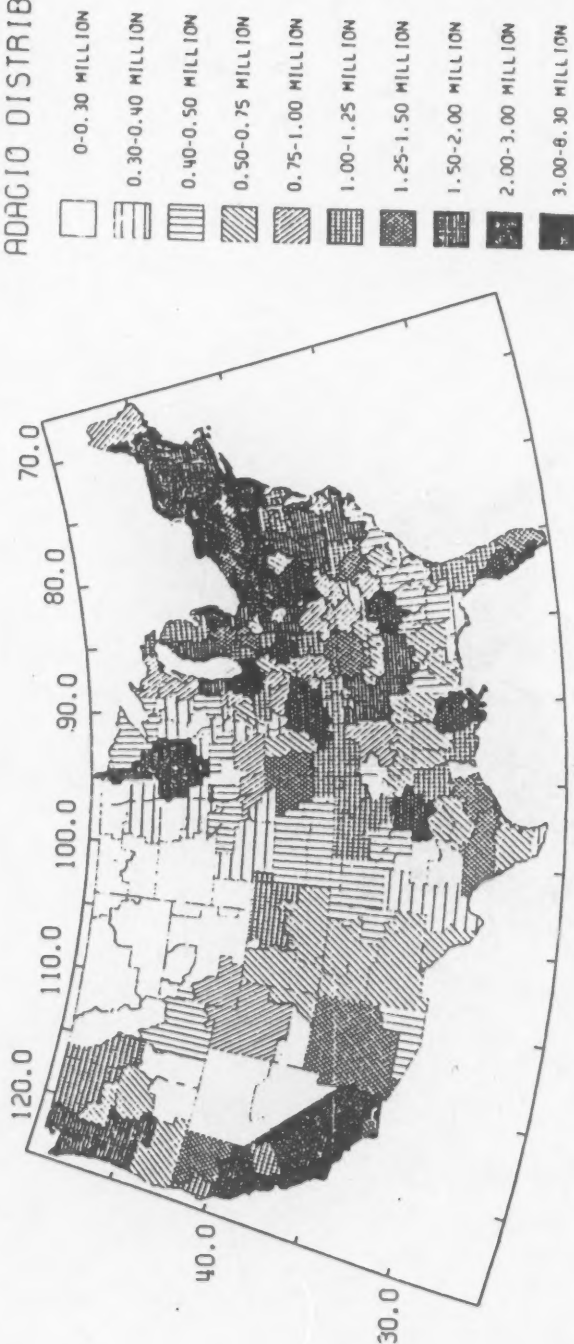
A. W. Voors, and B. S. H. Harris, Postattack Communicable Respiratory Diseases, R-OU-493, The Research Triangle Institute (November 1970), sponsored by Office of Civil Defense, p. 7-25.

Their derivation of this figure is presented on the page overleaf.

ORNL DWG 75-17537

FIGURE 2

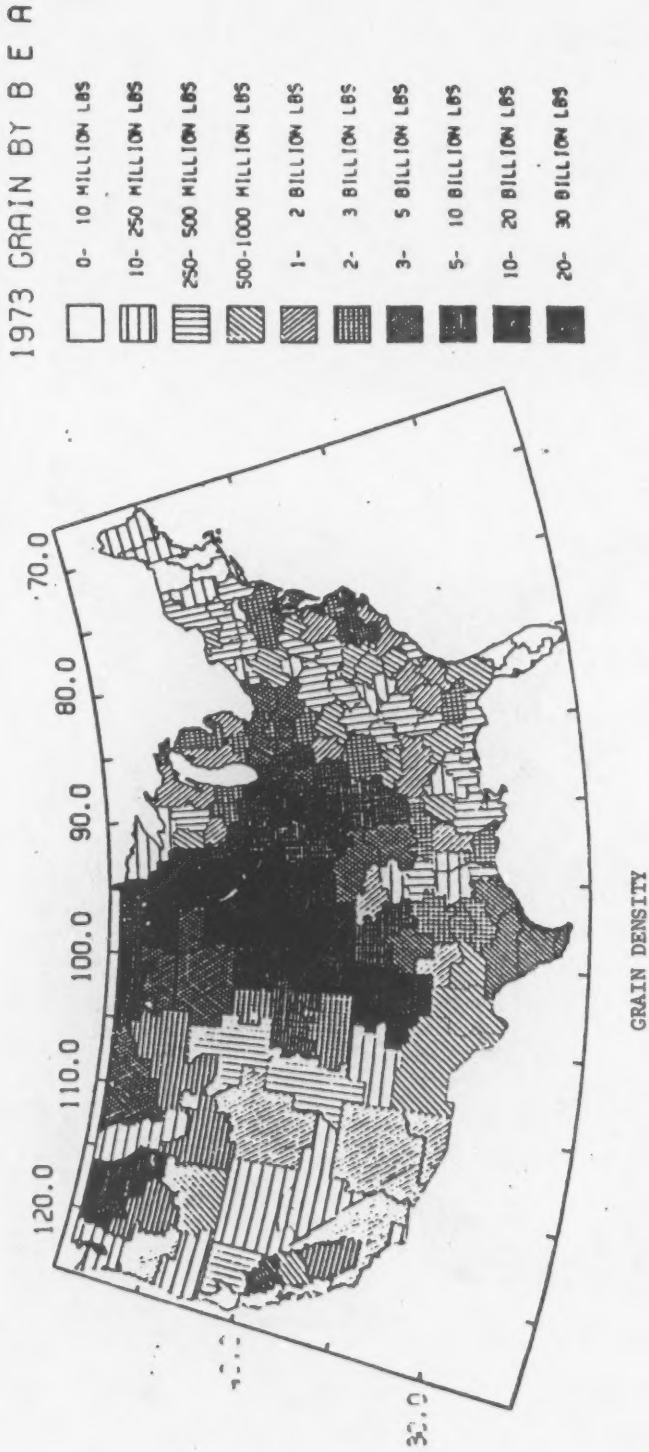
ADAPCIO DISTRIBUTION



This is a computer estimate of the density of population per county in the case of a crisis evacuation. This is of course interesting to compare to the map overleaf, which is a computer estimate of the amount of grain in each Business Economic Area (BEA) (p. 146).

C. M. Haaland, C. V. Conrad, and E. F. Wigner, Survival of the Relocated Population of the U.S. After a Nuclear Attack, ORNL-5041, Oak Ridge National Laboratory (June 1976), sponsored by Defense Civil Preparedness Agency, pp. 148-9.

FIGURE 3

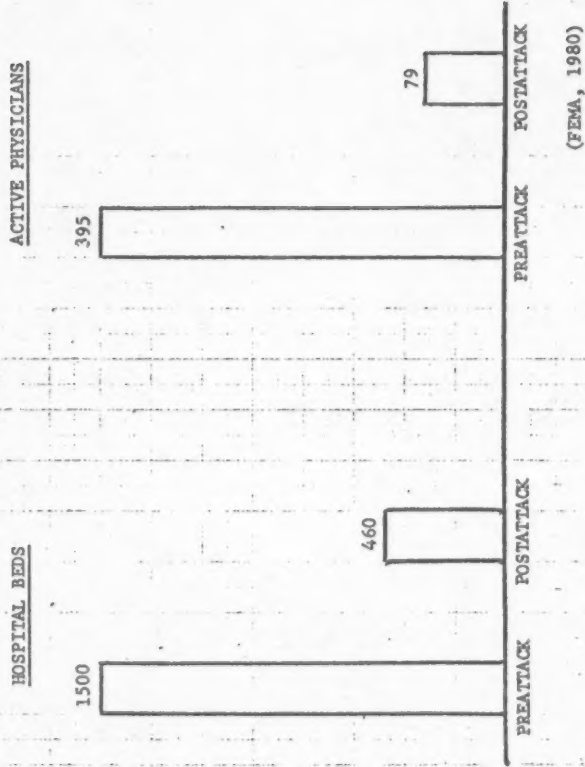


Haaland, Survival, p. 149.

FIGURE 4

U.S. MEDICAL RESOURCES AFTER NUCLEAR WAR

(IN THOUSANDS)



FEMA, "Material for the Record," in U.S. Cong., Sen., Hearing on Short- and Long-Term Health Effects on the Surviving Population of a Nuclear War, 96th Cong., 2nd. Sess. (June 19, 1980), p. 63.

FIGURE 5

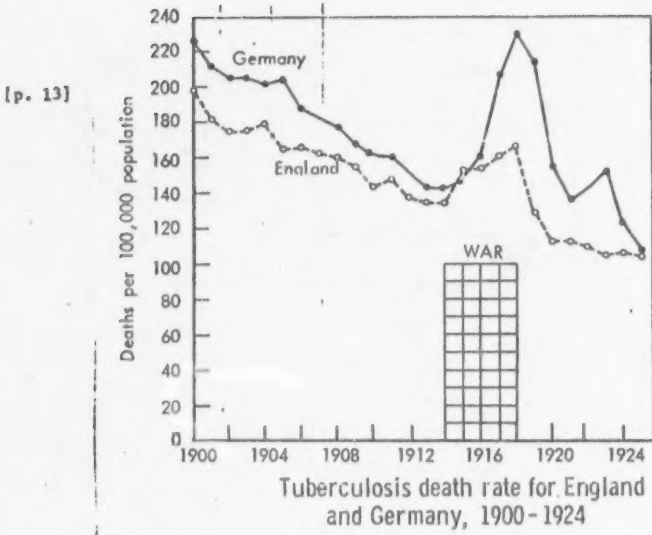
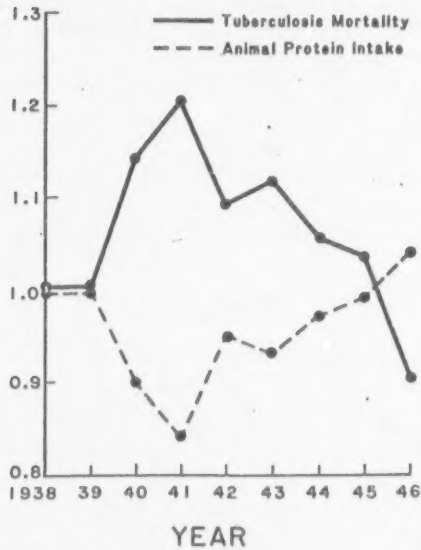


FIGURE 6

ENGLAND AND WALES TUBERCULOSIS MORTALITY
AND FIRST-CLASS PROTEIN INTAKE 1938-1946



Adapted from Mitchell: 1967

TABLE 1

SOURCES OF CASUALTIES

CAUSE	FATALITIES	INJURED OR AFFECTED
		(In Millions)
TRAUMA; FLASH BURNS	86	34
TRAPPED BY DEBRIS	5	2
SECONDARY FIRES	3	1
LACK OF WATER	1	4
INADEQUATE SHELTER VENTILATION	1	5
FALLOUT RADIATION	38	23
NET CASUALTIES:	134	33

(FEMA 1979)

Source:

Federal Emergency Management Agency, Analysis of Packages Comprising Program D-Prime (Washington, D.C.: FEMA, 1979), p. 3. This publication gives the pre-attack population as 237 million. Since our present-day population is about 225 million, the figures were all adjusted accordingly, so as not to differ from other casualty estimates used (by FEMA) that assume about 225 million. Those "affected" by fires, water, and lack of ventilation are said to be "forced out [of shelter] by..." This implies they might have been killed by radiation as much as by actual burns, dehydration, or suffocation.

Table 2

Medical Problems During the Attack and Post Attack Period.

<u>Medical Problem</u> (In approximate order of time in which inflicted)	<u>Imm.</u> <u>Eff.</u>	<u>Shelter Period</u>		<u>Survival</u>	<u>Long-Term Effects</u>	
	First Hour	First Day	First 0-4 wks.	Survival Period	Recovery Period	Future Genrtms.
Flash Burns	+					
Trauma	+					
Flame Burns and Smoke Inhal.	+	+				
Acute Radiation	+					
Fallout Radiation	+	+	+	+		
Suffocation & Heat Prostration		+	+			
General Lack of Medical Care		+	+	+		
Dehydration			+			
Communicable Diseases			+	+		
Exposure and Hardship			+	+		
Malnutrition			+	+		
Cancer						+
Genetic						+

Table 3

Principal Communicable Disease Countermeasures by Mode of Transmission

Countermeasure	Mode of Transmission		
	Enteric	Man-to-Man	Vectorborne
Antimicrobial therapy	+	+	+
Excreta disposal	+	-	-
Food hygiene	+	-	-
Immunization	+*	+	-
Potable water	+	-	-
Public information	+	+	+
Vector control	+	-	+

*Typhoid fever only.

Table 4

Infectious Diseases in the Post Attack Period.Communicable Diseases of Potential
Post-attack SignificanceReported Cases in
the U. S. in '979

Amebiasis	4,107
Diphtheria	59
Encephalitis, arthropod-borne, viral	1,266
Botulism food poisoning	45
Salmonellosis food poisoning	33,138
Hepatitis, A	30,407
Influenza	0.3*
Measles	13,598
Meningococcal meningitis	2,724
Plague	13
Pneumonia	19.7*
Rabies	4
Shigellosis	20,135
Smallpox	0
Tuberculosis	27,669
Typhoid fever	528
Typhus fever	69
Whooping cough	1,623

*Death rate per 100,000 in 1979.

Table 5

Potential Epidemic Diseases

Group 1:
Epidemic diseases of low incidence

1. Cholera
2. Malaria
3. Plague
4. Shigella
5. Smallpox
6. Typhoid fever
7. Typhus
8. Yellow fever

Group 2:
Serious existing diseases

1. Diarrhea
 2. Diphtheria
 3. Hepatitis
 4. Influenza
 5. Meningitis
 6. Pneumonia
 7. Tuberculosis
 8. Whooping cough
-

Mr. SHAMANSKY. Dr. Abrams, thank you for a very rational treatment of an extremely irrational topic.

Again, the institution calls me back. I will vote and come right back.

[Whereupon, the subcommittee was in recess.]

Mr. SHAMANSKY. Our next witness is Prof. Donald G. Pitts, College of Optometry, University of Houston, Houston, Tex. Welcome, Professor Pitts.

Professor PITTS. I want to thank the chairman and the committee for inviting me.

I will say that my area of expertise is not in ionizing radiation, but in the nonionizing radiation area of ultraviolet. So I am going to talk about ultraviolet radiation.

I would also like to inform the committee I am probably the only one who will serve as a witness who served with the 509th Bomb Group in World War II. If you don't know that was the U.S. Army Air Force group that dropped two bombs in World War II, and only two. As well, I was with the weapons tests that were conducted at Bikini in 1946, and I was also in Nevada during all the tests in the fifties. So I am probably the only one here that has seen nearly every detonation of nuclear weapons that we have had detonated. And, incidentally, I was at the Pacific high-altitude tests, the tea domes.

I have provided you with a written statement on the effects of ultraviolet radiation on the eye, and what I would like to do is take this data and try to answer some of the questions, because I am going to take firm data and apply it, knowing that the committee understands that we have some wide latitudes. We can't sit here and say this is for certain.

To start with, let's define some terms, because I am going to be using some scientific terms. Let's define the nanometer. The nanometer is nothing more than a measurement of the length of radiation, and let's explain it this way. I think I can do it fairly simply. If we take a meter, which is about a yard, and divide it into a thousand units, that is a millimeter. Now, if we divided that millimeter into a million units, we have a nanometer.

The other term I will be talking about is watts. We are talking about watts just like the light sources we have in the room, because it is a unit of power. If we had a 1-watt lightbulb, that would be one unit of power, and if we used this one unit of power for 1 second, that would be a Joule, or a unit of energy, because we have watts used during time and we are able to do work with it.

Then I will be talking about keratitis. It is nothing more than an inflammation of the cornea of the eye. Then I will talk about cataracts. This is an area that is really, really cloudy—and that's a pun as well as being truthful. Cataracts, of course, is a clouding of the lens of the eye, and we will have a few things to say about it.

Then we will talk about uveitis. Uveitis is a big Greek word that is used to explain an inflammation of the ciliary body and the iris, and the iris is what forms the pupil that we see through. If we talk about anterior, we are talking about that close to the front of the eye.

Now, let me turn the slides on.

[Slide.]

What I would like to do is show the committee what happens with ultraviolet radiation exposures. We are talking about very low levels of energy when we're talking about this type of radiation.

[Slide.]

First let's explain that most of the things we're talking about will be for the cornea of the eye. This is to show you where the cornea is located. We will be talking about the aqueous humor, which is the interior chamber, really, which the anterior uveitis occurs in, and we will talk about the lens, and we will talk about cataracts and the lens.

We will later talk just a little bit about some brand new data in the retina, so that most people, when they think about ultraviolet radiation, think about the anterior part of the eye and its effect on the anterior part, when, indeed, the retina is more susceptible than any other part of the eye. The damage to the retina is permanent, not like some of the other damage.

[Slide.]

The cornea, we have damage to it. Let's take a look at what happens when we expose the eye. Knowing that the cornea is that part of the eye that allows light to pass through before we can see, I think it is very easy to determine here that this animal could not see very much. Incidentally, the human would be the same way. This is exposure after 16 seconds.

[Slide.]

OK, anterior uveitis. This bright curved area is the cornea. This is a slit lamp or a microscopic picture of anterior uveitis, and the dark area is the anterior chamber. If you will look down below at the lower right-hand part, you will see all of this looks like a cloud.

Now, that is cells in the interior chamber, just cells and debris that have been caused by ultraviolet exposure.

Incidentally, the wavelength range necessary to produce this is very narrow. It is only 290 nanometers to 310 nanometers, so it is a very, very narrow waveband necessary to produce anterior uveitis.

[Slide.]

The third area is lenticular opacities. This is what they look like when you expose the eye. It is right in the anterior part of the lens. Initially, it starts out as white spots. So these are the three conditions that we cause.

[Slide.]

The fourth condition, that is just brand new, is this area here of the retina. This is part of the receptors that we see with in the retina of the eye. The amount of energy necessary to cause damage with ultraviolet radiation is 1/500th of that to cause damage from the visible spectrum. So UV is very effective in producing damage.

[Slide.]

Now, let's look at some of the data that we have here. This is all of the known data, all of the data known in the world right now on ultraviolet damage to the eye. This includes the rabbit, the primate, and the human. The human data is very, very limited, incidentally. It actually goes back to 1946.

There are two or three things we want to mention about these data. Over to the right are the low wavelengths. The animal or human being that is exposed to ultraviolet radiation doesn't know at the time of exposure that they are exposed. There is a 3- to 6-hour delay prior to knowing that you have been exposed. This is one of the most dangerous parts of ultraviolet radiation. You don't know about being exposed at the time exposure is being done. It is like X-rays—when you get an X-ray and you don't feel anything. The same thing happens here.

The other thing about it is that the cornea is very sensitive from about 210 nanometers all the way up to 315 nanometers. But the most effective wavelength is at 270 nanometers, 270 nanometers happens to be the absorption peak of the DNA molecule for ultraviolet radiation, almost precisely that wavelength. Because UV splits the DNA molecule into two pieces, is the reason why the cell dies. There is no recovery. The cell has to be replaced, and that is why this waveband of ultraviolet radiation is known as abiotic.

Now, we are pretty lucky here on Earth, very, very lucky, because these wavelengths are filtered out by ozone. In fact, from 85 up to about 200 nanometers is filtered out by molecular oxygen and nitrogen. But from 200 nanometers up to 300 nanometers, this very, very active region that is filtered out by ozone and is the problem here today.

Now, most people discuss ultraviolet radiation in the waveband region that remains. They discuss it from 300 or 320 nanometers up to 400, and this is the area that is not that important to us because we have lived and have adapted to this waveband.

To show you that we are in a very, very sort of limbo with our ecology—and it's a very, very nice level that we have—let's give you two examples. An individual who goes to the beach and lays down on the beach gets more ultraviolet radiation, about 50 percent more, than we do normally. If you talk to some of these

people, after their shower and when they're in the disco that evening they will describe to you that their eyes feel sandy, itchy, and sort of red, and they put some drops in to keep them white. These symptoms are because of too much ultraviolet radiation, just that little extra causes problems.

The other area that we are highly interested in is snow skiers. They have learned a long, long time ago that if they're out in the bright sunshine skiing, they must wear protection or they will have the same difficulties at night. So we are on that very close level of ecology, of enough UV to keep everything in the proper balance. Disturb it in any way and you disturb the ecological balance of the environment. That is a very important question.

Now, how do we disturb it with UV? Well, let's give a supposition—and most of the data that I will be talking about now actually comes from Dr. Kosta Tsipis of MIT. Let's assume that we have a large-scale nuclear attack. We know from looking at other people's data—well, looking at Tsipis' data, he says that 75 percent or more of the ozone layer will be destroyed. But let's be more conservative. Let's say 50 percent. The reason why I am conservative, I'm kind of honest, too, because 50 percent is easy to calculate. You can double things and get the answers.

What happens? Well, let's have the other slide on and this one off for just a moment.

[Slide.]

If we take the atmosphere on Earth and we calculate—and this is Kondratyev's data, appendix 7—and we calculate the amount of energy necessary to produce a cataract from sunlight on Earth, that's the 300 to 320 nanometer waveband, the top group in the slide, its radiant power on Earth, or irradiance, as we call it, is only 2.65×10^{-3} watts per centimeter squared. It is much easier just to say 265 milliwatts or 265 one-thousandths of a watt, and that's what we're talking about on the Sun. We can go outside and measure that.

Now, if we take its effectiveness and take a look at it, it means that if we were to sit with our eyes directed toward the Sun for 1 hour during midday, we could have a cataract. You would also have other damage, but you would have a cataract. You would have keratitis and a cataract, even though this band is not the most sensitive for producing keratitis.

Now let's open it up. If we have a nuclear conflagration that lets 50 percent of the radiant energy through, a 50-percent increase, the cataract exposure time is cut to one-half hour. You take the people who have now been in the shelters and put them out into the environment they're going to be foraging more than a half-hour. Not only that, you have now done away with the green vegetation that has been absorbing the UV and keeping it from being reflected from the ground up. UV will then increase by another $3\frac{1}{2}$ to 4 percent, so that will drop cataract exposure time even lower than 30 minutes.

Now, if we calculate the 50 percent of space radiation coming in, we find that there is 268×15^{-6} w/cm² coming in at 270 nanometers, which means that you could stay outside only 31 seconds under those conditions on Earth.

If, somebody says do your data work, and my answer is yes, they work. They protected the Gemini, Apollo, and Skylab people so far, and they protect people at Caterpillar Tractor. So the data do work on human beings and it is not a dream that I am talking about.

So really what I am saying is this: That if a conflagration comes such as 3,000 to 5,000 megaton war—and the people who are atmospheric physicists, which I am not, have defined the loss of the ozone atmosphere such as they have—then we're in trouble. Because even if we survive, we ourselves, in foraging for food, will be blinded because the corneal problems are permanent. Just twice the threshold data I have given to you causes permanent damage. If they don't have corneal problems, they're going to have cataracts, or they're going to have a combination of both, so they can't see. That's No. 1.

Second, this protein that was just talked about, that we need so highly, all of the animals are going to be in worse shape than we are because—maybe the rats won't, and I think cockroaches probably won't, either, or some of the insects won't—but they'll be in worse shape than we are because they will be also blinded.

Human beings have enough intelligence to be able to get in for protection but the animals don't. In fact, the ecology is so closely balanced that one of the serious diseases of dairy herds in the United States is a keratitis from overexposure of sunlight in the summertime—not the wintertime but the summertime.

So this ecological balance we are talking about is a very, very finely tuned thing. Any time you interrupt it, it is going to result in not only a loss of life but the people who survive will be severely visually handicapped and will probably be blind. The animals that will survive will also be blind. This type of situation does not bode well for our human survivors from such an exchange of weaponry.

Thank you very much.

[The statement plus a position paper on UV radiation of Professor Pitts follows:]

STATEMENT
OF
DONALD G. PITTS, O.D., Ph.D.
to
Committee on Science and Technology
Subcommittee on Investigations and Oversight
U.S. House of Representatives
Washington, DC 20515

Sept. 15, 1982

I wish to thank Chairman Gore and the members of the committee for asking me to come and provide information in my area of expertise. My area of expertise is in the biological effects of ultraviolet radiation on the eye (i.e., non-ionizing radiation).

I am probably the only one here today who served in the 509th bomb group during WWII. This the USAAF group that dropped the bombs on Hiroshima and Nagasaki as well as conducted the weapons test at Bikini. I also served on the Post-WWII Nuclear Tests at Indian Flats, Nevada.

You have been provided a written statement providing a position paper on the Ultraviolet Radiation Effects of the Eye. I should like to extend these data into the question at hand - what happens if the ozone layer were destroyed by a nuclear confrontation.

Lets start by defining some terms. I shall attempt to keep the definitions as simple as possible.

Nanometer -

is the unit of measure of the wavelength of light. A meter is a little longer than a yard. If a meter is divided into 1000 parts - each in known as a millimeter. Divide the millimeter into one million parts and that length becomes a nanometer.

Irradiance -

is the unit of power (watts) per area incident on a surface (M^2) or watts/ M^2

Cataract -

clouding of the media of the crystalline lens of the eye.

Cornea -

The anterior portion of the eye which looks like watch crystal. It is responsible for 65% of the power necessary to focus light on the retina.

I should like to address four issues:

1. What happens to the eye on exposure to UV.
2. The environment
3. UV effects - If the environment were changed
4. Protection against UV.

I am not an ionizing radiation or atmospheric physicist and must base my conclusions on their data while realizing that they do not all agree on what changes will take place. However the experimental data I will discuss can be easily modified to allow for any change. My weapons information is based on the data of Prof Karl Tsipis and National Academy of Science.

Now lets address the issue of the environment. Animal and plant life are in delicate balance with their environment. On page twelve of the position paper we have taken the data of Konrath for the solar atmosphere and have calculated the safe exposure duration for the human eye for the 300-320 nm portion of the UV spectrum. It illustrates that for the 300 to 320 nm waveband there are $0.265 \times 10^{-3} \text{ W/cm}^2$ of irradiance available from the sun. Using the present available research data, the maximum recommended exposure would be one (1) hour to produce cataracts. Why aren't we humans all demonstrating sun induced cataracts? Because (1) we walk upright and seldom look at the sun and, in fact, look down slightly but if we looked directly ahead the UV would only be 10% effective (2) the eyes are set deep in their sockets (3) we blink alot and (4) we have the bushy eyebrows

to scatter UV and make the exposure less effective. But we do have evidence that the balance is very sensitive. First, if we lay on the beach sunbathing our eyes become slightly red, itchy and feel like sand - this is due to too much UV next, snow skiers learned many years ago that protection against UV must be worn or they experience snow blindness - too much UV.

Lets Discuss Changes In The Environment:

- The most active UV is prevented from reaching earth by the ozone layer, molecular oxygen and nitrogen. The wavelengths between 85 nm and 200 nm are destroyed by molecular oxygen, 200 to 288 by ozone.
- Destruction of the ozone layer is controversial among atmospheric physicists with the arguments varying from no effect to a 75% depletion of the ozone layer. The maximum duration of the effects occurring from a few weeks to 3 years after the detonation. Lets assume a 2,000 to 3,000 megaton situation. Dr. Karl Tsipis of mit has stated that the ozone depletion would be very severe but some atmospheric physicists indicate different levels so let's assume an increase in the 40% to 60% level and for simplicity, let's assume a 50% reduction in ozone. What would be the effects of depletion or this much of the ozone?
- 1. Atmospheric physicists indicate that it would result in UV in the 200 - 288 nm wavelength range reaching the earth and produce an increase in amount of the longer UV wavebands by 200% to 300% (Fields). The most effective waveband in producing corneal damage at 270 nm would increase from zero to an irradiance of $12.8 \times 10^{-6} \text{ W/cm}^2$ - nm or $128 \times 10^{-6} \text{ W/cm}^2$ for a 10 nm waveband.

The allowable exposure duration would be:

t =

$$\frac{0.004 \text{ J/cm}^2 \cdot 31.25 \text{ sec}}{128 \times 10^{-6} \text{ W/cm}^2}$$

Twice the amount of UV exposure necessary to produce a threshold response results in permanent damage to the cornea. This damage would include opaqueness of the cornea which would not allow the optical image to reach the retina - the person or animal would be BLIND!! Exposure to ultraviolet results in extreme pain, photophobia, closing of the eyes, loss in visual acuity and a person is prevented from functioning visually.

The exposure would also result in cataracts. Cataracts are the single largest cause of blindness in the USA.

2. If UV at 300 nm were increased by 50%, the exposure duration needed to produce permanent UV cataracts would be reduced to 30 min.
3. Loss of vegetation would result in a further increase in UV reaching the eye which was not included in the above.
4. Individuals would be visually incapacitated and made blind unless protection against UV were provided because the dose is cumulative over 24 hrs. Research has shown that % threshold dose repeated throughout the day results in incapacitation visually.

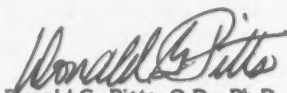
Both animal and human life would be severely visually impaired-blinded. Animals such as cattle, sheep, hogs, deer etc would be rendered blind!! Without trained personnel to care for both the blinded humans and animals, there would be little chance for long term - 1 - 3 year survival.

The CIAP Monograph 5 indicates that increases UV - 3 will be a decided stress on growth and productivity, beneficial effects of such UV increases are not to be expected and plant species vary considerably to this stress. Certain plant and animal species are already in danger from solar irradiance of UV and have developed strategies to overcome the damage by avoidance and cell damage replacement of parts or whole organisms.

Urback (Temple University) and Parrish (Harvard) have both indicated that there would be a substantial increase in skin cancer as the result of the depletion of the ozone layer. Others report a 2% increase in skin cancer for each 1% decrease in the ozone layer.

Finally, there are protective measures which can be taken by humans and might result is their protecting animals. If humans who survive retain their reasoning faculties, the mere avoidance of sunlight during the middle hours of the day will reduce the occurrence of photokeratitis and cataracts. Raising crops under some protection would enable food to be grown. Wearing of UV absorbing sunglasses or clear spectacle lenses would eliminate UV exposure to the eye. At any rate, the possibility of a nuclear confrontation and its subsequent devastation is not pleasant.

Thank you for having me to speak.


Donald G. Pitts, O.D., Ph.D.

A POSITION PAPER ON UV RADIATION

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Effects of Exposure to Ultraviolet Radiation

The threshold radiant exposure of the eye to ultraviolet radiation in the wavelength range from 200nm to 400nm is shown in Figure 1 and constitutes the action spectrum of the eye to UV radiant exposure.¹⁻⁷ An action spectrum defines the wavelength range that produces a defined biologic effect. In the case of Figure 1, the effects produced were called threshold and were determined by minimal damage to the cornea, iris, and lens of the eye from a biomicroscopic examination of the eye after exposure to certain wavelengths of UV for a predetermined duration. The action spectrum defines the efficiency of the radiation to produce a minimal damage effect and can be used to establish certain protective requirements. Figure 1 presents the action spectrum for ultraviolet radiant exposure for the rabbit (• and Δ), primate (▽ and ○), and the human (X). There are certain attributes which we will want to explore more deeply.

The corneal radiant exposure data from 315nm to 400nm are not considered part of the action spectrum of the cornea because the levels of exposure necessary to produce minimal damage to the cornea are quite high.⁶ For example, the threshold exposure level at 315nm is 450 times the corneal threshold at 270nm. Therefore, as well as can be determined, UV exposure at 325nm and for wavelengths up to 400nm are relatively innocuous when compared to the corneal and lenticular UV action spectra. This should not be taken to mean that the long wavelength ultraviolet is totally innocuous because there is some evidence that the UV-A may be responsible for cataracts.³

Photokeratitis:

The primary response of the eye to the UV waveband which begins at 210nm and extends to 315nm was the condition call "photo-ophthalmia" or "photokeratitis." This is the "welder's flash" that has been experienced by every arc welder who has struck the arc prior to lowering the protective helmet. After exposure to UV, there is a latency period

which depends on the intensity of the exposure but is typically 6-12 hours. The anterior part of the eye, the eyelids and the skin surrounding the eyes becomes reddened. There is the sensation of a foreign body or "sand" in the eyes and the person becomes very sensitive to light (photophobia), produces excess tears (lacrimation) and tightly closes the upper and lower lids (blepharospasm) to avoid pain. These acute symptoms last usually from 6 to 24 hours but almost all discomfort disappears within 48 hours. Fortunately, only extremely high exposures cause permanent damage and such exposures are very rare indeed. The importance of the symptoms lies in the facts that the worker is incapacitated visually during the acute symptoms and the eye does not develop a tolerance to UV exposure like the skin but becomes more sensitive to repeated exposures. Further, the radiant exposures necessary to produce photokeratitis are really quite low since only 4 m J/cm^2 at 270nm causes minimal damage. Radiant exposures which were twice the threshold value ($2X H_c$) resulted in permanent damage to the cornea.

Repeated Exposures:

The effects of repeated exposures to the cornea have been studied using the 350.7nm and 356.4nm wavelengths. A single exposure threshold of 52.5 J/cm^2 was established. It was shown that when repeated exposures were given and reparative mechanisms were accounted for, a continuous exposure of 41% of the single dose exposure could be received by the cornea without damage being observed. As long as $2.90 \text{ J/cm}^2/\text{hr}$ or less were delivered to the cornea in 3 hours or less there should be no corneal damage.

UV Induced Cataracts:

The second important response of the eye to UV radiant exposure is shown by the open and closed squares in Figure 1. These data define the action spectrum for the production of UV induced cataracts in the lens. The threshold radiant exposure H_L levels resulted in transient cataracts which disappeared in 7 to 14 days. Cataracts could not be

induced with radiant exposures below 295nm nor above 320nm despite using very high radiant exposures. Permanent lenticular changes were not induced until the radiant exposure levels reached twice the threshold value ($2 \times H_L$).

The cataract response occurs in a waveband which is transmitted to earth and the absorption of small amounts of UV daily may be responsible for inducing cataracts or accelerating the formation of other types of cataracts. There are an ever increasing number of papers appearing in the literature in recent years which implicates ultraviolet radiation as the causative factor in the production of cataracts, particularly the brown or brunescent cataract which occurs in the nucleus of the lens primarily in aging persons.^{8,9} Epidemiological literature indicates that the incidence of cataracts is related to the exposure to sunlight¹⁰ and that the incidence is related to UV exposure experienced by persons living at different latitudes. Examples include the claim that the incidence of cataracts is increased at all ages in Israel compared to Oxford, England, and that the incidence of cataracts increases in Tampa, Florida, in comparison to Rochester, New York, and in Manila, Philippines, when compared to Tampa.¹¹ The geographic areas in the USA with greater sunlight duration had a higher incidence of cataracts than the areas with shorter durations of sunlight. The issue of the relationship between sunlight and cataracts is far from settled because the epidemiological data are not definitive in establishing a cause-effect relationship and the biochemical evidence has not been experimentally proven.¹²⁻¹⁴ However, this evidence and experimental data in animals make a causal relationship a likely possibility.

Biochemical Alterations:

The photochemical and biochemical mechanisms underlying the response of the eye to ultraviolet radiation above 290nm have revealed some significant alterations in the proteins of the lens. Biochemical alterations of the lens also occurs with aging and cataract.

Although some investigators support the thesis that the brown or brunescent nuclear cataract results from solar photo-oxidation of the lens protein, the concept has not been experimentally proven. Harding and Dilley¹⁵ provide two major arguments against this hypothesis:

(1) "In brown nuclear cataract it is only the nucleus that is pigmented but any ultraviolet light reaching the lens will be absorbed by and, therefore, act on the proteins at the front of the lens. If proteins from the separated cortex and nucleus of the normal human lens are photo-oxidized in vitro, both go brown and at precisely the same rate."¹⁵

(2) Photo-oxidation of lens protein in vitro by sunlight destroys tryptophan¹⁶ but the proteins of the brown cataractous nucleus have as much tryptophan as those of the normal human lens,¹⁷ contrary to an earlier report."

Extrapolations from experimental animal data to humans must be qualified. Human cataractous lenses do show increased insoluble proteins and/or the presence of brown pigmented material with many of the same characteristics as the tryptophan photoproducts. Additionally, the human lens does absorb most of the near UV radiation striking the eye at an appropriate angle. UV induced cataracts have been experimentally produced in mice, rabbits, monkeys, and guinea pigs, and after both single and multiple daily exposures over a wide range of UV irradiances. Thus, UV is implicated as a potential cause of cataracts in humans.

Anterior Uveitis

A third important change which occurs in the eye as the result of exposure to UV is the production of a secondary anterior uveitis.⁶ This means that there is an inflammation of the posterior limiting layer (Descemet's membrane) and endothelium of the cornea which occurs as the result of exposure to ultraviolet radiation. This is characterized by a localized redness of the eye just lateral to the cornea, an aqueous flare, which looks like sunshine passing through a hole into a dark room illuminating dust particles in the beam,

and fibrinous materials deposited on the inside of the cornea. The experimental animals showed no signs of discomfort and the condition regressed spontaneously to normal within two days. This response was important because it had been postulated previously that the anterior uveitis preceded and was the cause of UV induced cataracts. The waveband which produced anterior uveitis began at 295nm and extended only to 310nm. The radiant exposure levels were comparable to the levels necessary to produce cataracts. Cataracts were produced both simultaneous with and independent of anterior uveitis and it was not considered as being the cause but occurred simultaneously with the anterior uveitis. When Descemet's membrane and the endothelium were involved, the cornea increased in thickness as much as 200%.

UV Sensitivity Due to Phototoxicity:

Dramatic increases in the sensitivity of the skin and the eye to ultraviolet and other spectral wavebands are induced by a variety of pharmaceutical compounds.¹⁸⁻²⁴ Damage which is light induced but not dependent on an allergic mechanism may be considered phototoxic. There are a number of antimicrobial and other pharmaceutical agents such as the tetracyclines, sulfanilamides, griseofulvins, salicylanilides and other drugs including the phenothiazines, the thiazides, psoralens, oral contraceptives and sulfonylureas which are phototoxic. Individuals who are taking such medications should avoid prolonged exposures to ultraviolet radiation, including sunbathing, until such period of time that the medication ceases to be a photosensitizer. The awareness of medications and their interrelations with ultraviolet radiation is fairly recent and is just beginning to be investigated so our knowledge is not complete in this area.

UV Effects on the Retina:

It appears that beginning around 300nm there is a small amount of UV radiation that reaches the retina. If this radiation is of the proper energy configuration (tuned) there is the feasibility of a photochemical burn.

Melanin of the pigment epithelium absorbs very strongly in the near UV close to the visible spectrum and there is every reason to believe that this absorption continues in the rest of the UV-A region of the spectrum. Fortunately, the lens absorbs strongly in this same region and protects the retina. In part, an older person should have much better protection from the crystal lens than the younger person. The fact that a mild RPE lesion of the retina with an intact lens looks very similar to Senile Macular Degeneration has been used as evidence that the retina is very sensitive to UV-A radiation. In addition, laser exposure (Ham) at 325nm and 350nm has produced retinal lesions with exposures of 5 nW/cm² for 1000s.

The effects of the UV-A on the retina has not been fully investigated and broad band as well as laser research is needed; however, what information that is available indicates that UV-A may be quite dangerous to the retina.

Summary of the Effects of UV Exposures

In summary, the ocular response to the ultraviolet radiation varies with the wavelength and the level of radiant exposure. The exposures up to wavelength 290nm resulted in damage primarily to the epithelium of the cornea and can be explained by the almost complete absorption of UV at 290nm and below by the epithelium. As the wavelengths increased to 315nm, the corneal damage appeared to shift to the internal layers of the cornea. The wavelength range between 295nm to 320nm is quite efficient in producing cataracts. Exposures above 320nm require higher levels of radiant exposure to produce damage. High radiant exposures result in severe reactions to all layers of the cornea regardless of wavelength. Thus, the cornea appears to give both a wavelength and radiant exposure response with the depths of the cornea becoming more involved at the longer wavelengths and at higher exposure levels.

When the action spectra and threshold values are studied, one finds the threshold radiant exposures from broadband optical sources for corneal damage are sufficiently

below the radiant exposure levels necessary to produce lens damage that the cornea should serve as a protective barrier for the lens (Figure 1). There are two situations in which the concept of the cornea serving as a protective barrier for the lens may fail. The first situation is for long term, low level repeated exposures which may be in the proper wavelength range but with radiant power levels below the corneal damage level and in which the cumulative effects produce lenticular damage. The second situation is when very high radiant exposure levels in the proper wavelength range are delivered in very short durations. Such exposures may result in minimal damage to the cornea but extensive damage to the lens in the form of cataracts. Examples of these two exposure situations would be sunlight and the laser. Sunlight would represent the low level, repeated cumulative exposures and the laser would represent the high radiant exposure source.⁴¹⁻⁴²

Discussion of Outdoor Risks:

The question of why the human on earth does not experience severe problems from exposure to UV deserves some discussion. The UV reaching the earth's surface provides little hazard to the human because of the filtering action by the earth's atmosphere. Absorption of UV in the region below 85nm and 200nm absorption of UV is due to molecular oxygen; while from 200nm to 238nm the absorption is due to ozone.¹ There are certain activities which involve a richer UV environment and which require protection or the threshold level to UV exposure will be exceeded.

Thus, the exposure to the ultraviolet from sunlight under normal living conditions can be considered somewhat safe because the eye is set below and behind the eyebrows and usually deep in the orbits in a relatively safe position. In addition, the line of vision is not directed usually toward the sun but at various angles to the sun which reduces the energy of the ultraviolet radiation reaching the ocular tissues. Of course, those few individuals who are particularly sensitive to exposure to sunlight (photosensitive) discover this fact early in life and attempt to avoid overexposure.

The amount of ultraviolet radiation that reaches the earth is highly dependent on the optical path through the atmosphere and the amount of moisture and other scattering mechanisms that are present. Since the maximum incidence of solar ultraviolet occurs only near noon at any given latitude. Much of the easily found data is for a 60° latitude (air mass 2). Such data would apply for morning and afternoon hours at lower latitude. However, scattered radiation is relatively richer in the ultraviolet than is the direct solar radiation. Snow reflects up to 80% of the ultraviolet. Altitude measures the amount at a given wavelength and reduces the threshold wavelength; therefore, it seems appropriate to run data for a shorter optical path than 60° latitude in giving an example of risk exposure. "Air mass 1" would not only be encountered in the tropics at noon but that level of radiation of UV would be also encountered on snowscapes at air mass 2 and possibly exceeded at high altitudes.

How Do We Protect The Eye Against Ultraviolet Radiation?

At the present time there are no official government standards which define the required protection; however, two recommended standards documents exist and present equivalent criteria. (Leach WM: Biological Aspects of ultraviolet radiations: A review of hazards, Division of Biological Effects, Bureau of Radiological Health, USD, HEW, Rep BRH/DBE, 73-3, 1970 and American Conference of Governmental Industrial Hygienists, Threshold Limit Values of Physical Agents Adopted for ACGIH for 1979, ACGIH, Box 1937, Cincinnati, Ohio, 1979).

Unfortunately, a reasonably simple instrument to measure the amount of UV radiation in the environment and provide a read-out as to the amount and type of UV protection required is not available. Therefore, the measurement of UV requires expensive instrumentation or use of the data which is published in the literature giving the power per unit area of the source (W/cm^2) for the wavelengths of interest. Fortunately, instrumentation may not be actually required because from the foregoing discussing, it

should be evident that UV radiation is dangerous and protection to prevent all UV radiation to about 330nm from reaching the eye is desirable. This can be achieved by using optical filters whose transmittance and absorption characteristics are known and assure that the undesirable radiation is eliminated. In addition, manufacturers of optical sources used commonly to industry should be required to provide tables and graphs of the output of the source by wavelength so that protection calculation can be made.

Ocular protection has commonly taken the form of spectacles, goggles, shields or helmets which use absorptive or reflective filters to control the undesirable optical radiation. Filtering of optical radiation by absorption is accomplished by incorporating materials within the lens; for example, iron oxides incorporated into the glass melt absorb about 95% of the infrared radiation. Reflective filters can provide very effective protection when properly chosen to transmit the visible spectrum and reflect the unwanted radiation. It is dangerous to assume the protective characteristics of a lens from its color or tint because the tint may or may not provide protection.²⁵ For example, the grey or neutral glass lens usually transmits both ultraviolet and infrared radiation in sufficient amounts so that it should not be used for industrial protection against UV or IR but has been used as a sunglass lens because its grey color does not affect color perception.

To help understand some of the principals of ocular protection let us look at some of the transmittance curves of selected optical materials. Figure 2 shows the transmittance of five commonly used optical materials, including ophthalmic crown, CR-39 and polycarbonate. Most optical glass lenses (lens 1) are manufactured from ophthalmic crown glass which begins to transmit UV at about 280nm which quickly increased to about 90% at 340nm. This means that ophthalmic crown glass cannot be used for UV protection unless an absorber is incorporated into the melt. The CR-39 curve (lens 3) represents a polymer that has been used for spectacle lenses for many years. The lens 5 is a CR-39 lens which contains UV absorbers and which should provide excellent protection against any UV

source.

Polycarbonate is a plastic material which possesses excellent physical characteristics against low temperatures and impact but tends to scratch easily unless properly coated and transmit UV radiation and is shown as lens 2 and lens 4 in Figure 2. Lens 2 is a clear polycarbonate which ^{does not} contain UV inhibitors and, as can be seen, transmits UV beginning at 290nm and attains an 86% transmittance at about 380nm. Lens 4 is polycarbonate with UV absorbers which affords excellent protection against UV since it absorbs all UV to about 380nm. The small amount of UV transmitted in the 380nm to 400nm waveband should not pose a hazard to the eye because the threshold radiant exposure is above 200 J/cm^2 which requires a massive amount of UV to reach this level.

An ophthalmic lens with transmittance characteristics which reduces ultraviolet radiation to a minimum such as lenses 4 and 5 should be prescribed for a number of different types of patients. Surgical removal of the crystalline lens leaves the retina susceptible to damage from the increased transmittance of ultraviolet radiation since all UV which had been absorbed by the crystalline lens can be transmitted to the retina. Absorption of this UV radiation by filtering is necessary to insure that the retina is not damaged from UV exposure when the eye is aphakic. Prescribing protection for the aphakic patient will prevent a solar retinitis from overexposure to sunlight by preventing UV-A and UV-B radiation from reaching the retina. Patients with cataracts often experience excessive glare when driving or when they are outside in the sunlight such as fishing, golfing, and gardening. A UV absorbing lens would prevent the ultraviolet radiation from reaching the lens and causing scatter and fluorescence within the cataracterous lens. Patients who are taking photosensitizing drugs which cause a number of ocular problems and which are triggered by ultraviolet radiation should be provided UV absorbing lenses. Finally, UV absorbing lenses should be used for any patient who has a vocation or avocation which requires excess exposure to ultraviolet radiation to eliminate or reduce the threat of UV induced cataracts.

In addition, it must be remembered that snow skiing and sunbathing at the beach constitute the highest exposure to UV as far as the eye is concerned. The sand on the beach reflects UV and the eyes are directed toward the sun. Snow constitutes the best reflector of UV radiation known and UV is richer at high altitudes.

Summary and Conclusions:

The effects of radiant exposure of the eye to ultraviolet radiation have been discussed. Examples of optical materials used in protection were given. The following conclusions can be drawn:

1. The primary response of the eye to exposure to UV-A in the 210nm to 315nm wavelength range was the cornea and included the epithelium, stroma and endothelium. Twice the radiant exposure threshold ($2 \times H_C$) resulted in permanent damage to the cornea.
2. The secondary response of the eye to exposure to the UV-B in the wavelength range from 295nm to 320nm was the lens in the form of anterior subcapsular cataracts. Twice the threshold radiant exposure ($2 \times H_L$) resulted in permanent cataracts.
3. Finally, it has been shown that ultraviolet radiation in small amounts is quite harmful to the eye and adequate protection is necessary in environments which use ultraviolet radiation in the manufacturing process and when there is excessive exposure to sunlight. Examples of protective materials have been discussed to assist in understanding the principles of protection.
4. It was recommended that all aphakic patients, cataract patients, photosensitive patients, skiers, sunbathers and anyone who spends excessive time in the sun or a rich UV environment be prescribed ophthalmic lenses which protect the anterior ocular segment and the retina against exposure to ultraviolet radiation.

Air Mass 1

NM

300-320	0.265×10^{-3}	watts/cm ²
320-340	0.865×10^{-3}	"
340-360	1.219×10^{-3}	"
360-380	1.526×10^{-3}	"
380-400	1.610×10^{-3}	"

Table derived from Kondratev, appendix 7

Calculated Direct Solar Radiation in an "Ideal" Atmosphere.

Assuming an effectiveness of 0.003 (ACGIH for 315nm)

In the 300-320 Band $0.265 \times 10^{-3} \times .003 = 7.95 \times 10^{-7}$
 a 0.8μ watt/cm²

Table 10, ACGIH Recommended exposure = - 1 hr.

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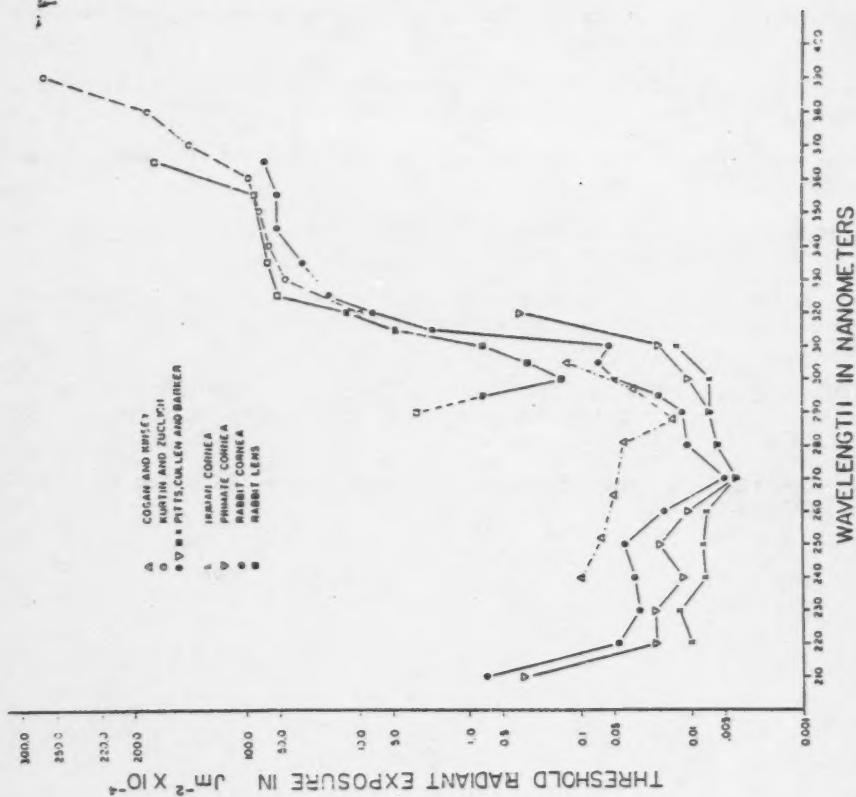


FIGURE 1. ULTRAVIOLET RADIANT EXPOSURE ACTION SPECTRUM

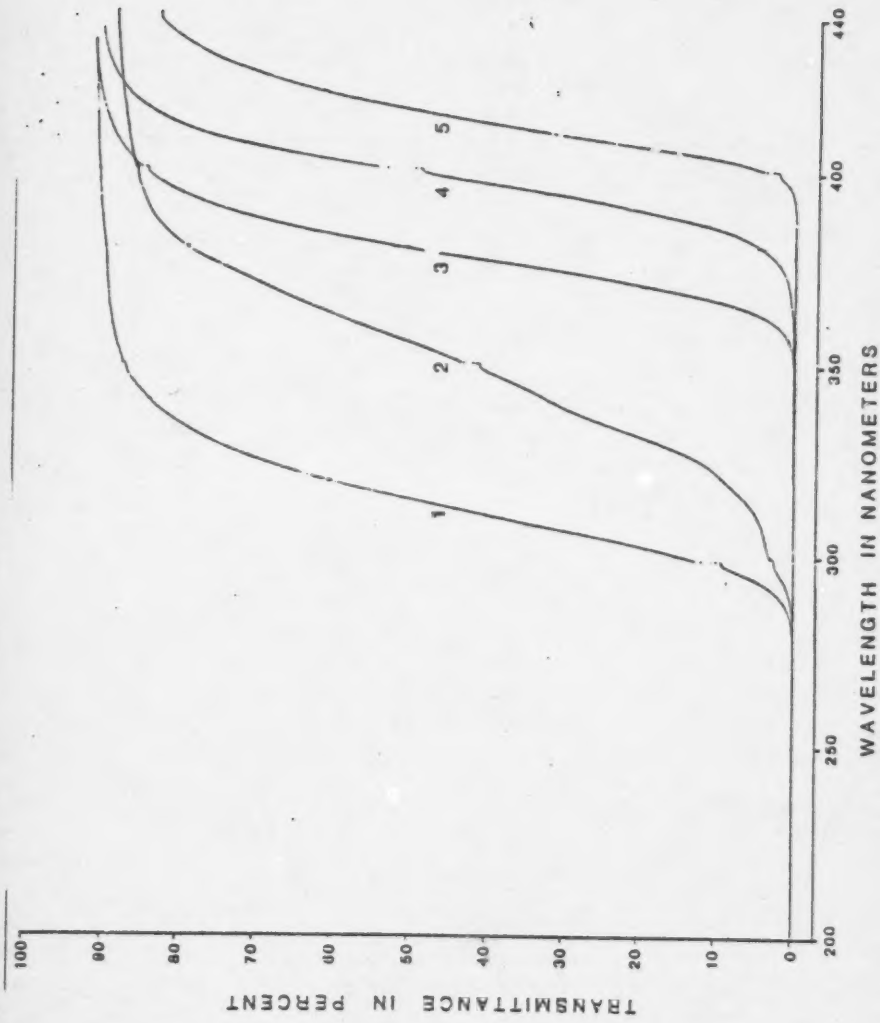


FIGURE 2 REPRESENTATIVE OPTICAL MATERIALS

ULTRAVIOLET THRESHOLD AND RELATIVE EFFECTIVENESS
FOR THE RABBIT CORNEA AND LENS

Wavelength nm	Corneal Radiant Exposure J/cm ²		^{CORNEAL} Relative Efficiency	
	Rabbit	Primate	Rabbit	Primate
210	0.7	0.33	0.007	0.012
220	0.046	0.021	0.11	0.19
230	0.03	0.022	0.17	0.18
240	0.033	0.012	0.15	0.33
250	0.041	0.020	0.12	0.20
260	0.018	0.011	0.28	0.36
270	0.005	0.004	1.00	1.00
280	0.011	0.006	0.45	0.67
290	0.012	0.007	0.42	0.57
300	0.022	0.011	0.10	0.36
305	0.07	---	0.07	---
310	0.05	0.02	0.09	0.20
315	2.25	---	0.002	---
320	7.5	9.6	0.0005	0.0004
325	18.0	---	0.0003	---
330	~ 30.0	41.1	~ 0.0002	9.7x10 ⁻⁵
335	30.1	---	0.0002	---
340	---	58.3	---	6.9x10 ⁻⁵
345	50.0	---	0.0001	---
350	50.0	61.5	0.0001	6.5x10 ⁻⁵
355	50.0	---	0.0001	---
360	50.0	83.4	0.0001	4.5x10 ⁻⁵
365	65.0	---	0.0001	---
370	---	130.	---	3.0x10 ⁻⁵
375	> 55.8	---	< 0.0001	---
380	---	170.	---	2.0x10 ⁻⁵
385	> 23.2	---	< 0.0002	---
390	---	253.	---	1.6x10 ⁻⁵
395	> 23.5	---	< 0.0002	---

TABLE I

Total Permissible 8-Hour Doses and
Relative Spectral Effectiveness of Some
Selected Monochromatic Wavelengths (28).

<u>Wavelength (nm)</u>	<u>Permissible 8-hour dose (mJ/cm²)</u>	<u>Relative spectral effectiveness (SX)</u>
200	100.0	0.03
210	40.0	0.075
220	25.0	0.12
230	16.0	0.19
240	10.0	0.30
250	7.0	0.43
254	6.0	0.50
260	4.6	0.65
270	3.0	1.00
280	3.4	0.88
290	4.7	0.64
300	10.0	0.30
305	50.0	0.05
310	200.0	0.015
315	1000.0	0.003
		$\Sigma = 5.193$
		$\bar{x} = 0.35$

Mr. SHAMANSKY. Thank you, Dr. Pitts. Your prepared statement will be admitted to the record.

I don't think I am different from anybody else. I find the topic so overwhelming that I'm a little shaken. I don't know how you handle—My imagination falters in trying to comprehend that.

Let me begin, if I may, with Dr. Abrams. We have had the administration suggest a civil defense program whose projected costs are in excess of \$4 billion, I believe. I'm being a little flip but note that it says Columbus, Ohio should vacate to Granville, Ohio. You can imagine, Granville is the home of Dennison University and it would fit in one's side pocket. I don't know how you would get it over there given the amount of time.

Do you see any civil defense scenario in which the effects you have just discussed could be prevented?

Dr. ABRAMS. Within the framework of the Federal Emergency Management Agency's scenario which we have discussed—and I think it's a reasonable one for a massive exchange between the two superpowers—it seems to me as though all of the elements that would promote the spread of infection and epidemic would be operative, and that no civil defense plan could prevent the most massive devastation and annihilation the world has ever known.

One example is the crisis relocation plan, which is really the most important part of the civil defense planning in this country, and, I might add, in the Soviet Union.

Mr. SHAMANSKY. Of course, that doesn't make it any more valid that the Soviets are doing it, too.

Dr. ABRAMS. Not a bit. Not a bit. Not only that, but to the best of our knowledge there has never been a rehearsal in a single Soviet city of a crisis relocation plan. But the fact of the matter is—and Dr. Drell can attest to this as eloquently as any—the instantly re-targetable instrumentation now at hand might well affect those who are being relocated.

The important point I would make about this is that, with the present targeting plans, 80 percent of the hospital beds, 80 percent of hospitals, 80 percent of doctors, 80 percent of nurses, the vast complement of individuals there to handle the medical problems of survivors will simply not be available, or the antibiotics.

We have tried to look at the relationship between resource need and resource availability, not just in terms of antibiotics but blood plasma, plasma replacements, surgical forceps, the whole gamut of things. There is a remarkable disparity under the very best of circumstances. So that I think I can say confidently that there certainly is no credible medical response to this kind of massive exchange.

Mr. SHAMANSKY. Dr. Abrams, I would like to pursue that, because, while you were responding, the word "surreal" kept coming into my head. There has to be a surreal quality as you talk with the people at FEMA, as we use the acronym around here. What do they say when you mention that?

Dr. ABRAMS. Their point is—and this is an appropriate point—that planning for civil disasters is an intelligent thing to do, and that the medical profession—and this is correct—should be involved in planning for a civil disaster. There is an extrapolation of something that is manageable and that is frequently compared to a

volcano, if you will, or a volcanic eruption, to a setting which is not only unimaginable but which has no relevance to the kind of disasters that we are planning for.

Mr. SHAMANSKY. That is why I used the word "surreal." At some place or another there is a disconnect between the reality of, say, a civil disaster and that of nuclear war. To me, as you used the expression, a Mount St. Helens or whatever came to mind. We get floods regularly in various parts of Ohio. But we're not talking about that. And yet FEMA extrapolates from the rational response to such an emergency and then, as you say, extrapolates to this. Are they serious?

Dr. ABRAMS. Well, I think they are as serious really as many individuals at governmental levels, who somehow or other obscure the difference between a conventional war and a nuclear war. It seems to me as though there has been a major effort—particularly when we talk about winnable nuclear war, survivable nuclear war or whatever—to simply suggest that a massive nuclear war is just one end of a continuous spectrum. Whereas I think those of us who have dealt concretely with the medical consequences believe not only that it's not just part of a spectrum, but that there is an extraordinary gap that separates the two.

My sense is that civil defense planning in its traditional sense—for example, a shelter system, when you're talking about a conventional war, with bombing and so on and so forth, may well make some sense. Even there, however, one has to begin to think of what happens with nuclear weapons; namely, the shelter perhaps as a gas chamber, the shelter as a heat chamber, as a suffocation chamber. The shelter, really, instead of providing protection, will be a tomb, possibly.

Mr. SHAMANSKY. Thank you, Dr. Abrams.

Dr. PITTS, if I may, in the 1975 report of the National Academy of Science on the ozone effects of nuclear war, ozone depletion levels in the range of 30 to 70 percent were forecast. Would blindness be a possible consequence at these depletion levels, and what would be the effect of persons exposed to lower depletion levels of, say, 10 to 30 percent?

Professor PITTS. At those levels—and that's the reason why I selected 50 percent, because it is sort of in between—blindness is definitely not only a possibility but I would say occur in most people—that is the reason why the people going from Columbus, Ohio to the small town in Ohio, if the ozone layer is opened up for them, they're not going to survive, either, because they will be blinded. They won't be able to get around. So blindness not only is possible; it is almost a certainty.

Mr. SHAMANSKY. How about on the lower level, getting out beyond the center of the target?

Professor PITTS. On the lower level, if you put it down in the 30 percent level, you are going to have some damage, because now you are getting below twice threshold, or at least you will get enough people below twice threshold that will find out things are going on, so that it is survivable. But it isn't comfortable at all. You won't have the medical support to "treat" it.

Mr. SHAMANSKY. Can you tell us when within the period following a war ultraviolet radiation would be at its worst, and can you

tell us how long people would have to remain indoors to escape the effects?

Professor PITTS. If you take a look at the atmospheric physicists who have done publishing, it looks like the effects begin fairly maximum at about three weeks and continues through 3 years—

Mr. SHAMANSKY. How long?

Professor PITTS. About 3 years.

Mr. SHAMANSKY. It seems to me that what you're saying is that civilization as we understand it—I mean, life as we know it on this planet, that has been adopted over billions of years, just would not and could not function?

Professor PITTS. It was suggested earlier that we have sunglasses for all animals, but I would like to submit that sunglasses won't protect against ultraviolet radiation. In fact, you cannot predict protection with any sunglass by its color. We do have lenses available in this country that will protect—in fact, there are only about six lenses in this country that are fairly new on the market. They have gotten into the act now. They are fairly new on the market and they will protect. So you have to be careful in making broad statements about sunglasses.

For example, my lenses protect and they're clear. They have a cutoff at around 390 nanometers. Nothing below that gets through the lens that I have.

Mr. SHAMANSKY. Would we issue them with birth certificates? [Laughter.]

Professor PITTS. It looks like you would have to, doesn't it. It's an insurmountable task I think to try to solve a logistics problem such as this.

Dr. ABRAMS. It is also worth pointing out that sunglasses will not protect, obviously, against ionizing radiation—

Professor PITTS. Oh, no.

Dr. ABRAMS [continuing]. And that lens opacities, otherwise known as cataracts, are one of the commonest reactions of the eye to levels of 100 rads or more of radiation.

Professor PITTS. That's right.

Mr. SHAMANSKY. At the lower levels, lower depletion levels, are there effects in addition to or other than blindness?

Professor PITTS. Yes. In fact, John Parrish at Harvard University and Fred Urbach at Temple University, both of those people are dermatologists and they predict at that level a tremendous increase of skin cancer. It would be well over 50 percent of the skin cancer that we know now. That's one thing.

The other thing is, if you get into that 30-percent level you're talking about, the individuals will undergo a constant keratitis that is not treatable.

Mr. SHAMANSKY. I want to pose this one last question to both of you. The work that FEMA does, does it make any sense to you in this context?

Professor PITTS. No, not for me, and the reason why I say this is because I live in Houston, Tex., and, as you know, we have hurricanes come through. We have hurricane evacuation plans which don't work. This is another example—

Mr. SHAMANSKY. And that is a civil disaster, right?

Professor PITTS. That's right, it is a civil disaster. It just doesn't work.

Mr. SHAMANSKY. Dr. Abrams?

Dr. ABRAMS. In the context of a massive exchange—and it seems to me as though in any nuclear war between the superpowers, we would almost inevitably move up to that level—it is very, very hard to see how a productive and creative response could be created.

I would say there is one circumstance under which there is clearly merited close investigation, and that is the possibility of a single weapon in the hands of a terrorist or of a fanatical group and the explosion of that single weapon, and a well-defined medical response. We are talking now about any—

Mr. SHAMANSKY. But basically you're talking about a civil disaster—I mean, as we have customarily defined that—

Dr. ABRAMS. Exactly.

Mr. SHAMANSKY [continuing]. A locus, a defined area, with the rest of your society intact.

Dr. ABRAMS. That's exactly right.

Mr. SHAMANSKY. But once you get beyond the Hiroshima or the Nagasaki, which are isolated events, in fact, all bets are off, right?

Dr. ABRAMS. Right.

Mr. SHAMANSKY. I want to thank counsel for really a good question, because this is where we're going ultimately.

Based on your experience, do you feel the general public is beginning to comprehend the enormity of what you are talking about and do we have a role here, in addition to your roles, of informing the public of what we are really dealing with?

Dr. ABRAMS. My own sense is that there has been an enormous awakening and concern around the country since 1979. This obviously has had to do with many different groups.

I might say that the physicians, as a group, really have become involved since that period. Physicians for Social Responsibility has moved from 29 members up to 16,000 members, and that this conservative group—because doctors are a very conservative group—

Mr. SHAMANSKY. As are lawyers. I'm quite aware of that, being a lawyer.

Dr. ABRAMS [continuing]. They view this as a conservation of life and health issue. Whether you speak, as I did not too long ago, to a few hundred Iowa general doctors in Iowa City, with 70,000, or whether you speak in Los Angeles or around the country, there is a huge amount of interest in getting informed about this.

Mr. SHAMANSKY. Is the medical profession, as a profession—let's say the AMA, a reasonable establishment and well regarded in conservative circles—do they have a program?

Dr. ABRAMS. They have strongly endorsed the concept of making certain that physicians are thoroughly aware of the medical consequences. I can tell you that physicians are generally poorly educated on this.

We initiated a course at Harvard Medical School this year on the health consequences of nuclear weapons and nuclear war, and I expect it is one of the two or three in the Nation. The students accepted that with great enthusiasm. There was not only good at-

tendance, but it will be repeated next year. It was illuminating for those of us who taught as well as for the medical students because it was an area they really had not been exposed to in coherent form.

Mr. SHAMANSKY. Have you formed an evaluation as to the conscientiousness of the Soviet medical fraternity?

Dr. ABRAMS. The Soviet doctors are clearly being made more aware. As you know, the International Physicians for the Prevention of Nuclear War recently—our president, Bernard Lown and Jim Muller, who is the secretary, both cardiologists, and John Pastore, who is a cardiologist, all were over there on June 24 in a television program which was beamed to perhaps 100 million Soviets, in which the three of them, with three of their Soviet counterparts, talked about the health consequences of nuclear war.

Mr. SHAMANSKY. You mean in the same vein that you're talking here?

Dr. ABRAMS. In precisely the same vein. I have seen the transcript. On October 13 it is going to be broadcast over public television in this country, so that people can see for themselves—not only was it uncensored, but CBS, ABC, and NBC were invited to be in on the thing. So they are hearing it and hearing it very loudly.

Mr. SHAMANSKY. That's encouraging.

Dr. ABRAMS. Beyond that, we have at least 100 or 150 press clippings from Pravda, Izvestia, of the international meeting in Cambridge, England in April, which emphasizes the conclusions of that scientific, professional medical meeting, nonpolitical meeting, about the medical consequences. Clearly, this was spread across the Soviet Union. So the Soviet people are surely hearing about it and are beginning to understand it.

Dr. Chazov, the head of the Soviet delegation and Chairman Brezhnev's personal doctor, has made it clear in unmistakable terms to the Soviet people on television—we have a videotape of that—that the Soviet Union would be destroyed not for decades, not for generations, but beyond your lifetime and our lifetime.

Mr. SHAMANSKY. I regret to say this is the first time I have ever come across any reference to such an informational exercise.

Dr. ABRAMS. We have translated the text of the articles on the one hand, and also the videotape of Chazov, and now this last videotape of the American and Soviet doctors discussing this issue. As I say, it will be on public television on October 13, so one and all can clearly see that the message is getting across.

Mr. SHAMANSKY. Professor Pitts, would you like to comment?

Professor PITTS. Yes. I think most Americans are like you. I don't think they know the meetings have even been held, much less know the content of the meetings. It is unfortunate that our news system does not get this information across to us. I think this committee could serve as a focal point or some way of educating the American people to really know what we're talking about.

The average American doesn't know. You see, we are talking about sophisticated Americans with a good education, so on and so forth. The average American has no more idea than the man in the Moon what a ton of TNT does, much less what a megaton of this stuff does.

Dr. ABRAMS. Just in answer to your first question, it seems to me as though many have the concept that yes, in nuclear war a lot of people will be killed, a lot of people will be injured, but then there is going to be a survival period and the Cadillacs will roam and the Toyotas will be here, there and elsewhere.

My own judgment is that at an official level, perhaps with an international approach to this issue, with the kind of solid, factual documentation that must be the basis for a proper appraisal, that more people in this country and in other countries will really understand what the nature of survival is.

Mr. SHAMANSKY. I would like to just end this panel on the note that I hear the Secretary of Defense defend the references to a "winnable" nuclear war, only because he says you don't plan to lose a nuclear exchange, which is almost beside the point. I don't know how you handle it at all. I don't know how you do it. I mean, it's nice and simple, but it alludes me.

Well, thank you, gentlemen, for your testimony. It was very interesting. We have submitted various questions to you and we would make a part of the record your responses at a later date.

Mr. SHAMANSKY. I would like to call to the witness table Prof. James P. Friend, Prof. John W. Birks, and Prof. Arthur H. Westing. The overall topic that you gentlemen will be addressing obviously is the effect on the atmosphere.

Professor Friend, would you like to begin your testimony?

STATEMENTS OF PROF. JAMES P. FRIEND, DEPARTMENT OF CHEMISTRY, DREXEL UNIVERSITY; PROF. JOHN W. BIRKS, DEPARTMENT OF CHEMISTRY AND COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES, UNIVERSITY OF COLORADO; AND PROF. ARTHUR H. WESTING, PROFESSOR OF ECOLOGY, HAMPSHIRE COLLEGE

Professor FRIEND. Thank you very much for inviting me to be here and for this opportunity.

I have a written statement—

Mr. SHAMANSKY. Which we will make a part of the record, without objection.

Professor FRIEND. Thank you.

Mr. SHAMANSKY. You can paraphrase or however you wish.

Professor FRIEND. What I would like to do is just read the list of atmospheric effects that I address myself to and describe briefly what the results of some calculations were that were done by Dr. Julius Chang of Lawrence Livermore Laboratory to estimate some effects of a large nuclear exchange.

Mr. SHAMANSKY. Please proceed.

Professor FRIEND. First we are concerned with worldwide effects, long-range and long-term worldwide effects. For your information, I was a member of the National Academy of Science workshop and committee that ran the workshop producing this report, "The Long-Term, Worldwide Effects of Multiple Nuclear Weapons Detonations." So what I have done, with Dr. Chang's help, is to provide some sort of a reassessment or an update of our estimates of what the atmospheric effects would be.

Basically, there are two types of effects. One is the chemical effect, changing the atmospheric composition, leading ultimately to the reduction of ozone. The other is an accumulation of effects leading to climate change.

The first one that I have listed specifically is reduction of stratospheric ozone by NO, nitric oxide, created in the fireballs of the nuclear explosions. This again would lead to effects listed further here.

The second one is injection of aerosols into the stratosphere from blown-up surface materials and possibly from intense fires ignited by heat and radiation from the blasts. This would, in turn, lead to effects listed also below.

The third one is changes in radiation intensities in the atmosphere and at the surface of the Earth. In particular, there would be enhanced intensities of ultraviolet radiation at wavelengths below about 340 nanometers, the same nanometers that Dr. Pitts talked about. Also there would be somewhat diminished intensities of radiation in the visible region.

Finally, there would be changes in climate due to changes in heating and cooling caused by the aforementioned changes in composition of ozone, nitrogen dioxide, and aerosol concentrations, particularly in the stratosphere.

I devoted most of my efforts essentially to these long-range effects through stratospheric-transported materials and effects in the stratosphere rather than the troposphere, which we considered would be relatively short-lived effects and not necessarily transmitted directly on a worldwide basis. John Birks here, with his work, has shown how possibly short-term, severe tropospheric effects, fires and so forth, could lead to a wider scale, longer scale climate change because of severe alteration of the properties of the surface of the Earth.

Now, I think the big question on our mind here is the effects of ozone reduction, so I would like to put that off for just a moment and dispense with the other part which has to do with changes in climate or changes in composition of the atmosphere. We have no basis for changing our estimate of the climate changes from what they were thought to be in the National Academy report. They are thoroughly described there. The state of our knowledge in how to represent these changes in models has not improved significantly because the multiple component system that we perceive makes up the climate is highly interactive, with a lot of what we call feedbacks. Various parts of the system interact with each other in an extremely complex way and we don't know the details well enough to be able to represent or predict accurately what the changes would be, although as I conclude, we still foresee a possibility of a nontrivial climate change from large-scale nuclear war——

Mr. SHAMANSKY. You said "nontrivial"?

Professor FRIEND. Nontrivial, yes. There is almost a philosophical point here, that we tend to think of climate changes as being reversible or variable around some mean, but there is a possibility which we are not sure of, that climate may be shifted irreversibly as a result of sufficiently drastic changes of the surface of the Earth.

Mr. SHAMANSKY. It is not beyond the imagination of science?

Professor FRIEND. That is correct. But we just don't know how to predict that.

So essentially, the estimated climate effects went something like about a half a degree celsius temperature change averaged around the world for a period of a year or two. That kind of cooling effect would be due to the dispersing of particulate material around in the stratosphere. That is not the same as the kind of particulate effect that you will hear from Dr. Birks.

With regards to the ozone reduction due to the injection of nitric oxide, Dr. Chang ran some calculations at our request and he used a modern-day scenario, namely, the OTA arsenal. He decided that the best thing to do would be to just imagine you blew the whole thing up. That was 13,000 megatons. He came up with the result that the ozone abundance in the stratosphere would rapidly diminish to a minimum and then slowly recover back to natural levels again. That minimum level in the Northern Hemisphere would average about 63 percent from the 13,000 megatons.

Mr. SHAMANSKY. Would you repeat that? I want to make sure I grasped what you were telling me.

Professor FRIEND. The maximum depletion in ozone, or zone concentration—

Mr. SHAMANSKY. Would be depleted 63 percent?

Professor FRIEND. By 63 percent, yes.

Mr. SHAMANSKY. And 37 percent would be all that would remain?

Professor FRIEND. All that would remain, at that point of maximum depletion, which would last—the recovery time now is shorter than we thought it was in the old National Academy report. It is now about 2 years rather than 4 years.

In the National Academy report our estimate, using a nonmodern scenario, if you will, a lot of large yield weapons, came out to about 50 percent ozone reduction. So we are talking about the same basic magnitude of things, 50 or 63 percent. The uncertainties certainly cover those differences and make them indistinguishable.

I think the one new thing which is different is that there is a relatively rapid recovery time. So in terms of physical effects, we see an ozone reduction to about the same magnitude, perhaps a little bit more than was estimated in 1975, but a more rapid recovery.

From the point of view of the effectiveness of the various weapons within the arsenals, in this scenario we had many more small yield weapons due to what OTA believes is the constitution of the U.S. arsenal, with many weapons of the order of 100 kilotons, 130 kilotons, in that order.

Dr. Chang, in his computations, did something I thought was pretty interesting. He said, "Well, let's imagine that we blow up only the U.S. arsenal of weapons with yields less than 500 kilotons." That resulted in a maximum ozone diminishment of 5 percent. Because the lower yield, weapons place the nitric oxide lower in the stratosphere, and there is less of it.

Then he did another calculation, in which he said let's imagine that both sides blow up all of their weapons with yields less than 2 megatons. That resulted in a 40 percent maximum decrease in ozone. So it turns out, then, that the weapons greater than 2 mega-

tons, which are mostly those possessed in the scenario by the Soviet Union, would be responsible for the additional ozone destruction beyond 40 percent, about 23 percent, because their yields are substantial and they place the nitric oxide high in the stratosphere which means it would reside there longer and have more of an effect.

Mr. SHAMANSKY. Does that complete your testimony?

Professor FRIEND. That, essentially, is the results.

[The prepared statement of Professor Friend follows:]

WORLDWIDE ATMOSPHERIC EFFECTS FROM NUCLEAR WARFARE

Statement to the Sub-Committee on Investigations and Oversight
Committee of Science and Technology

By James P. Friend
Department of Chemistry
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September 15, 1982

Introduction

This report is an up-dating of the estimated atmospheric effects resulting from the massive exchange of nuclear weapons. In 1975 the National Academy of Sciences issued a report (see below) on the long-term effects from a hypothetical nuclear war involving the release of 10,000 MT of explosive energy from weapons of 1 MT and 10 MT yields. Effects on the atmosphere, agriculture, natural life and humans were assessed. For the purposes of the present, up-dated assessment of atmospheric effects, a computer-based model calculation was performed using an assumed "modern" arsenal, namely that assumed for the mid-1980's by the Office of Technology Assessment in their 1981 report "The Effects of Nuclear War". It was assumed (for the present model calculation) that the entire arsenal of 13,400 MT total yield was used. In this scenario, most of the U.S. weapons have yields of less than or equal to 0.35 MT while most of the USSR weapons are in the range of 0.5 - 1.5 MT yields and some have yields of 20 MT. A table in this report displays the OTA's arsenal estimates in two tables taken from Appendix B of their report.

Atmospheric Effects

The worldwide atmospheric effects resulting from massive nuclear war which are foreseen are:

- a. reduction of stratospheric ozone by NO created in the fireballs of the nuclear explosions. This effect would give rise to effects listed in (c) and (d) below.
- b. injection of aerosols into the stratosphere from blown-up surface materials and possibly from intense fires ignited by heat and radiation from the blasts. This would in turn lead to effects listed in (c) and (d) below.
- c. changes in radiation intensities in the atmosphere and at the surface of the Earth. In particular there would be enhanced intensities of ultraviolet radiation at wavelengths below about 340 nm. Also there would be somewhat diminished intensities of radiation in the visible region.
- d. changes in climate due to changes in heating and cooling caused by changes in ozone, nitrogen dioxide (NO_2), and aerosol concentrations in the stratosphere.

Our concern is with trace substances (gases and particles) in the stratosphere for the manifestation of global effects. The processes of removal (rainout and dry deposition) from the troposphere are thought to be so rapid and efficient that direct tropospheric effects would be localized and of short duration (of the order of 10-20 days or less).

Estimates of Effects

a. Ozone Reduction

A computation was made of ozone reduction from a massive exchange of strategic nuclear weapons amounting to 13,400 MT explosive yield.

This corresponds to the OTA's estimates of the total strategic nuclear forces of the Soviet Union (10,100 MT) and the United States (3,300 MT). The computations were performed by Dr. Julius Chang of the Lawrence Livermore Laboratory using a computer model that stimulates chemical reactions and transport in the atmosphere. The model is similar to the one used by Chang to produce the estimate of the ozone reduction used in the 1975 National Academy of Sciences report, "Long-Term Worldwide Effects of Multiple Nuclear Weapons Detonations". In that study, the total explosive yield was taken as 10,000 MT. However, the compositions of the arsenals were quite different from that assumed by OTA in that the NAS assumed about one-half in 1 MT weapons, whereas the OTA's estimated arsenals contain weapons with yields mostly in the range of 0.1 - 2 MT. The United States arsenal was estimated to be comprised mainly of weapons with yields less than 0.5 MT, while the Soviet Union is estimated to have most of its arsenal in weapons with yields in the 0.5 - 1.5 MT range.

Table 1 shows a comparison of the conditions and the calculated ozone reductions for the two scenarios (NAS, 1975 and OTA, 1981). The peak ozone reductions in the Northern Hemisphere are not different within the uncertainty limits. This similarity is due in part to the fact that the present model, though different from the earlier one in detail, predicts the effect of NO on ozone reduction to be nearly the same as the earlier model. The statement in the Summary of the OTA report that "the NAS report may have been more alarmist about the possibility of damage to the ozone layer than recent research would support" was based on a previous chemical model. In our current understanding (see NAS report 1982, "Causes and Effects of Stratospheric Ozone Reduction") the oxides of nitrogen ($\text{NO}_x = \text{NO} + \text{NO}_2$) are approximately as effective in ozone reduction as they were thought to be in 1975.

Table 1 shows a significant difference between the two scenarios in

the time that it would take for the ozone change to recover to one-half of its peak value. The shorter time of two years for the present scenario is the result of the lower altitude of injection of NO by the lower yield weapons. Material in the lower stratosphere is removed to the troposphere faster than material at higher altitudes. In this regard it is a notable model result that all of the U.S. weapons with yields less than 0.5 MT would cause only a 5% ozone reduction and that all of the combined stockpiles of weapons with yields less than 2 MT would cause a 40% ozone reduction.

The change in ozone concentration caused by nitric oxide occurs in a series of complex chemical interactions which vary with altitude. Indeed, according to present models, increases in nitric oxide can lead to ozone increases in the lower stratosphere. However, at higher altitudes where most of the ozone exists, the effect of nitric oxide additions is to reduce ozone concentrations. Because of the nature of the chemical interactions, the problem of determining ozone changes from additions of nitric oxide is a non-linear one. That is, doubling the NO additions will not lead to a doubling of the estimated ozone decrease, but instead will give a less-than-doubled result. We do not now have detailed up-dated calculations to provide estimates of ozone changes for a range of NO inputs (or total megatonnage exploded). However an idea can be gained by examining the working curve, Figure 1.9, of the NAS 1975 report on nuclear detonations effects. There it is indicated that the 10,000 MT war would give rise to an increase of 1000% in NO_x column density which in turn would lead to a 50% decrease in ozone column density. If the yield were 5000 MT leading to a 500% increase in NO_x column density, the ozone column change would be 37%. Further, we would find that a 25% ozone decrease would result from a 150% increase in NO column density corresponding to an explosive yield of 1500 MT from nuclear weapons. Putting

this general scheme into the current context, one can readily see that a reduction of released megatonnage by about a factor of ten, (from 13,400 to 1,500) would give a change in estimated maximum ozone reduction of about a factor two, from 63% to somewhat greater than 25%.

b. Radiation at the surface

The presence in the stratosphere of increased amounts of NO_2 , lowered amounts of ozone, and higher abundances of aerosols would cause changes in the intensities of radiation at the surface. An important increase in the intensity of biologically effective ultraviolet (BUV) radiation would occur because of the ozone change. The NO_2 and aerosols would give rise to relatively small decreases in the intensities of radiation in the visible region of the spectrum. the change in BUV is estimated here to be no greater than about 350% caused by the 63% ozone reduction based on a rough estimation from information given in the NAS 1975 report.

c. Climate change

The chemical composition changes noted in (b) above (viz. in O_3 , NO_2 and aerosols) lead also to changes in the distribution of heating and cooling of the atmosphere and at the surface, leading further to possible changes in atmospheric processes that effect weather climate. Our ability to model these compositional effects for the purpose of estimating climate changes has not improved since 1975. Since the magnitudes of the current and prior estimated effects are similar, the conclusions about climate changes are essentially unchanged. Thus we still find reason to say that there is a "nonegligible" chance of a significant short term climatic cooling due to changes in ozone concentrations. Since the current estimate of the duration of the ozone decrement is about two years rather than four years as before, a shorter duration of the cooling effect is expected. However, as the NAS report noted,

the climate change may not be reversible.

The climate effects from particles injected into the stratosphere were estimated by the NAS report to be similar to that of a large volcanic injection such as caused by Krakatoa in 1883, viz. about 0.5°C lower average surface temperature for a few years. Again, the differences in scenarios are not large enough to cause a change of the estimated Fallout.

d. Distribution of Radioactive Fallout

The patterns of radioactive fallout deposited on the surface were estimated in the NAS 1975 report to be similar to those known to have occurred from atmospheric weapons tests in the 1-50 MT range. The general patterns to be expected from the current arsenals should be similar to the prior patterns but somewhat scaled down, perhaps by about one-half to allow for enhanced scavenging effects in the lower yield bursts, and possibly for reduced fission/fusion yield ratios.

e. Uncertainties and Unknowns

As noted in the NAS 1975 report the basic physical principles necessary to provide estimates of the atmospheric effects of large scale nuclear war are well-enough known. Since 1975 our understanding of chemical interactions has improved to the point where we might estimate the uncertainty in peak ozone reduction to be within a factor of 2. This is similar to the estimates of uncertainty of calculated ozone changes from halocarbons released in the atmosphere (see NAS, 1982 report). The uncertainties in climate change remain substantial and even cover the possibility that instead of cooling there maybe a warming.

The unknowns in this "problem" are the precise magnitudes of the many quantities that characterize the multi-causal, highly interconnected, interactive system that we call climate. The hope for increasing our knowledge lies generally with continued support of climate studies. In particular, for this problem (and for others such as increased emissions of nitrous oxide from fertilizer use), there needs to be attention paid to the integration of chemical effects into climate modeling studies.

TABLE 1
Nitric Oxide/ozone effects

Scenario	Current Estimate*	1975 N.A.S.
	OTA (1981) stockpile	500 x 10 MT 5000 x 1 MT
Total explosive yield	13,400 MT	10,000 MT
Amount of NO produced	1.3×10^{36} molecules	1×10^{36} molecules
Peak Ozone change (reduction) in		
Northern Hemisphere	63%	50%
Range (uncertainty)	40 - 80%	30 - 70%
Time to recovery to 1/2 (O_3)	2 years	4 years
Peak change in erythymal dose	300 - 350%**	300%

*Calculations performed by Julius Chang of Lawrence Livermore Laboratory

**Crudely estimated from Appendix 5A in NAS Report

Mr. SHAMANSKY. Thank you, Dr. Friend.

Did you want to make a comment?

Professor FRIEND. I wanted to add that in my statement there is a table which lists the various scenarios, the explosive yields, the amount of NO produced, estimated ozone changes and uncertainties, and also the peak change in the erythymal dose, which is the UV radiation intensities that lead to reddening of the skin.

Mr. SHAMANSKY. Thank you very much. It will be made a part of the record, as will the OTA weapons estimates used by Dr. Chang.

Professor FRIEND. Those erythymal changes are the order of 300 to 350 percent, so we are talking about tripling the amount of UV dose normally received.

Mr. SHAMANSKY. Professor Birks

Professor BIRKS. Thank you, Mr. Shamansky.

First of all, let me say I am very grateful for being invited to be here and to be able to testify.

What effects, if any, would a nuclear war have on the Earth's atmosphere? This is a question which Paul Crutzen and I began to address approximately 1 year ago as part of a study sponsored by the Royal Swedish Academy of Sciences. Scientists from both East and West were asked to contribute articles evaluating as best possible the effects of a nuclear war on the oceans, the atmosphere, agriculture, global supplies of food and freshwater, human behavior, and the global economic consequences. The results of these studies, including our findings for the atmosphere, were published in the June issue of *Ambio* this year. Here I would like to summarize our results for you.

Any study of possible nuclear war effects must begin with some assumptions concerning the numbers and sizes of nuclear weapons detonated and the locations of the targets for those weapons. Our evaluation of the atmospheric effects of a nuclear war is based on a scenario provided by a panel of advisers for the *Ambio* study. The scenario is neither the least nor the worst of what might happen in a nuclear war. Targets are assigned to only 14,737 of the approximately 59,000 tactical and strategic warheads expected to be in existence in 1985. These targets include nearly all cities in the Northern Hemisphere having populations greater than 100,000, missile silos, military installations of all sorts, industrial complexes, oil and gas fields and refineries, energy stockpiles, chemical plants, hydroelectric stations, and a variety of other economic and military targets. In terms of total explosive energy, these targets utilize 5,742 megatons, or less than half of that available in the nuclear arsenals of the United States and the Soviet Union.

Mr. SHAMANSKY. The *Ambio* weapons table will be incorporated in the record.

Professor BIRKS. In consideration of what these thousands of nuclear explosions would do to the atmosphere, our attention was drawn to the many fires that would result. To begin with, much of the damage caused by a nuclear explosion is a result of fire. For example, following the relatively small nuclear explosion above Hiroshima, fire consumed every combustible object within 2 kilometers of the hypocenter. During a nuclear war it would not be possible to extinguish fires because of nuclear contamination, loss of wa-

terlines and firefighting equipment, and perhaps most importantly, loss of people.

Besides the fires in urban and industrial centers, we expect that vast forest fires would start, extensive grasslands and agricultural fields would burn, and it is likely that many natural gas and oil wells would be ruptured, releasing huge quantities of oil and gas, much of which would also burn. In our estimation, the most serious atmospheric effects of a nuclear war would result from these many fires.

As an example of how these fires could affect the Earth's atmosphere, we have taken forest fires into special consideration. It is difficult to estimate how much forest area might burn as a result of a nuclear exchange. For the purposes of our study, we assumed that a total area of 1 million square kilometers, or about 360,000 square miles, of forests spread around in the northern hemisphere would be consumed by wildfires. This is probably an underestimate, as it is only 20 times larger than what is now annually consumed by wildfires, amounts to only 4 percent of the temperate and boreal forest lands, and is not larger than the combined urban areas. The U.S. Forest Service has estimated that a nuclear attack on the United States of approximately 1,500 megatons would burn a land area of between 400,000 and 6 million square kilometers in the United States alone. Thus, our estimate of 1 million square kilometers throughout the Northern Hemisphere is low in comparison.

Where there is fire there is smoke. Based on measurements of particulate matter produced by forest fires, we estimate that the burning of 1 million square kilometers of forest would inject between 200 and 400 million tons of particulate matter into the atmosphere. Because of their small size——

Mr. SHAMANSKY. Excuse me. Would you repeat that number again?

Professor BIRKS. Between 200 and 400 million tons.

Mr. SHAMANSKY. Between 200 million and 400 million tons?

Professor BIRKS. Yes.

Mr. SHAMANSKY. Thank you.

Professor BIRKS. Because of their small size, the residence time of smoke particles coming from forest fires is about 5 to 10 days. These particles are strong absorbers of sunlight and infrared radiation. If we assume that the forest fires will last for 2 months, a spread of 200 to 400 million tons of aerosol over half of the Northern Hemisphere would cause an average particle loading such that the integrated vertical column of particles is equal to 0.1 to 0.5 gram per square meter. As a result, the amount of sunlight reaching the surface of the Earth would be reduced by a factor between 2 and 150 at noontime in the summer. These reduction factors would be larger during other seasons and during other times of day. Thus, it is quite possible that for several weeks following a nuclear war more than 99 percent of the sunlight would be blocked for much of the Northern Hemisphere.

This estimate is based only on forest fires. Large forest fires in arctic regions are commonly accompanied by fires in peat bogs which may burn over 2 meters in depth. The production of aerosol by such fires has not been included in this estimate, nor does this

estimate include contributions from combustion in cities, industrial centers or oil and gas wells. It is possible that particulate matter produced in very hot fires, such as those that would rage in cities and in oil and gas fields, would be injected to very high altitudes so that the atmospheric residence time would be much longer than the 5 to 10 days which was applied to our forest fire calculations.

In the atmosphere, for example, the residence time for particulate matter is of the order of years. A longer residence time for the smoke particles in the atmosphere would both prolong the darkening effect and increase its magnitude. The screening of sunlight by smoke has not been considered in previous studies of nuclear war effects. We believe this finding to be the most significant result of our study.

Besides shrouding the Earth with a dark smoke layer, it is also possible that the thousands of fires would cause a severe photochemical smog to develop. The ingredients of smog are oxides of nitrogen, hydrocarbons, and sunlight. Because light is required, the photochemical smog can only develop once the fires cease to burn and the smoke begins to be removed from the atmosphere. The oxides of nitrogen necessary for smog formation are provided by the nuclear explosions themselves and by the fires.

Nuclear explosions produce nitrogen oxides by heating air to very high temperatures. The explosion of 5,742 megatons of nuclear weapons would introduce about 13.4 million tons of nitrogen oxides into the atmosphere. Because of forest fires, we estimate an input of another 15-30 million tons of nitrogen oxides. Other atmospheric inputs from forest fires include 200 to 400 million tons of carbon monoxide and tens of millions of tons of reactive hydrocarbons, mostly ethylene and propylene, important ingredients in photochemical smog.

Natural gas and oil fields were among the major targets of the nuclear war scenario we were asked to evaluate. Although it is not possible to target all of the more than 800,000 gas and oil wells in the world, certain areas where production is both high and concentrated are likely targets of a nuclear war. Saudi Arabia's 800 oil wells, for example, outproduce the United States 590,000 oil wells. Furthermore, many gas and oil wells are under high pressure and when ruptured would release gas and oil at rates much higher than when under control and in production. It would take fewer than 300 breakages of the magnitude of the famous gas well blowout at Gassi Touil in the Sahara to release natural gas at the current rate of worldwide consumption. Known as the "Devil's Cigarette Lighter," this well powered a 200-meter-high flame with 15 million cubic meters of gas per day until it was capped.

For the purposes of our model calculations, we assumed that oil and natural gas would be released and burned at a rate equal to current consumption. Furthermore, we assumed that 25 percent of the natural gas would be released unburned. The methane, and especially the ethane and propane, because of their high reactivity in the atmosphere, contributed significantly to the photochemical smog formation.

Using these illustrative assumptions, we modeled the photochemistry following a nuclear war. Our calculations show that in the Northern Hemisphere levels of ozone at the ground would increase

from 30 parts per billion in the present time to levels approaching 160 parts per billion for some months following the war. These calculations are for latitudinal averages, and since the fires occur on land, we expect that ozone levels over land would be greater than 160 parts per billion and over oceans would be less. With time, substantial increases in other pollutants such as the strong phytotoxicant, peroxyacetyl nitrate, or PAN, to several parts per billion may also occur.

We would like to emphasize that this is only an example of what might occur as a result of a nuclear war. The formation of photochemical smog is complicated by the presence of the fire-produced aerosol. It is possible that the smoke particles would absorb some fraction of the oxides of nitrogen and thus partially cleanse the atmosphere of this pollutant. The amount of smog formation is also highly dependent on the quantities of hydrocarbons released as a result of the breakage of natural gas wells, which may be more or less than what we have used in our example.

Also, we have not included atmospheric inputs from the fires in cities. Between 5 and 15 percent of the world's oil production goes into the manufacture of high polymers. Considering that most of these materials are stored in cities, and assuming a lifetime of 10 years for such materials before disposal, we may estimate that there is roughly a year's production of petroleum stored in cities as plastics and other polymers. There is, of course, an enormous quantity of lumber and wood products stored in cities, as well as a non-negligible amount of asphalt in the streets. The combustion of all of these materials would certainly contribute to both the smoke production and to the oxides of nitrogen and reactive hydrocarbons necessary to photochemical smog formation.

Past studies of the atmospheric effects of a nuclear war, such as the U.S. National Academy of Sciences study of 1975, which Dr. Friend has just described, have emphasized primarily the effects of nuclear explosions on the stratospheric ozone layer. Whereas ozone is undesirable at the ground level because of its toxicity to both animals and plants, ozone in the stratosphere provides a protective shield against harmful ultraviolet radiation from the Sun. Although oxides of nitrogen tend to cause ozone levels in the lower atmosphere to increase, in the upper atmosphere where the chemical composition and light spectrum are quite different, nitrogen oxides act as a catalyst for ozone destruction.

Our model does not predict significant ozone depletion in the stratosphere for Ambio's 5,742-megaton nuclear war scenario. This is because very few weapons having yields greater than 1 megaton are used in this scenario. Only explosions having yields greater than 1 megaton result in fireballs that rise into and stabilize in the stratosphere. For comparison with previous studies, we also evaluated the effects of a second nuclear war scenario. This scenario considers a 10,000-megaton war in which the weapon yields are equally distributed between 1-megaton and 10-megaton weapons—in other words, 5,000 1-megaton and 500 10-megaton explosions. This scenario resulted in an initial depletion of the ozone column of greater than 50 percent throughout most of the Northern Hemisphere with an exponential recovery time of about 3 years, in good agreement with past studies. Thus, should the United States and

Soviet Union choose to use larger yield weapons, large reductions in the protective ozone shield are to be expected. This would result in an increase by severalfold of the biologically damaging ultraviolet radiation reaching the surface of the Earth.

There are other mechanisms by which the oxides of nitrogen produced by the nuclear explosions and fires might be injected into the stratosphere. For example, it is possible that enormous fires in cities or in oil and gas fields could produce plumes of hot air that penetrate the tropopause and carry oxides of nitrogen into the stratosphere. Another possibility is that the heating of the troposphere due to the absorption of sunlight by suspended particulate matter would result in a change in the dynamical structure of the atmosphere such that the tropospheric air containing nitrogen oxides would be mixed into the stratosphere and thereby cause ozone depletion.

In conclusion, for many weeks following a nuclear war the atmosphere would be loaded with particulate matter to such an extent that the amount of sunlight reaching the surface of the Earth would be substantially reduced. It is quite possible that greater than 99 percent of the sunlight would be blocked during this time. As the fires subside and the particulate matter is deposited, it is likely that a severe photochemical smog situation would develop throughout the Northern Hemisphere and persist for several more weeks. Because of the reduced sunlight and damage by air pollutants such as ozone and PAN, it is unlikely that there would be any significant yield of food crops during the first year following a nuclear war if the war occurs during the growing season—

Mr. SHAMANSKY. Excuse me. Who would need it?

Professor BIRKS. Well, that's a good question. I think if you look at the testimony that has been provided today, certainly there would be initial survivors, people who survive the initial blast and heat, millions of survivors initially. But there are so many other ways that people would die, many of them overlapping, such that there is a tremendous overkill. It is a good question, as to whether there would be people to need this food.

The other question with regard to food crops is the matter of distribution, who would remain to distribute this food to the people?

Additional damage to food crops by solar ultraviolet radiation would result if the stratospheric ozone shield is also reduced.

These atmospheric changes would also have important human health effects, and such effects would be in synergism with radiation exposure, lack of adequate food supplies, and lack of medical care. The darkened sky would undoubtedly add to the psychological stress of the initial survivors.

The atmospheric effects of a nuclear war would damage many natural ecosystems. For example, it is possible that most of the phytoplankton and herbivorous zooplankton in more than half of the Northern Hemisphere oceans would die as a result of the darkening by fire-produced aerosol. Phytoplankton are microscopic green plants that begin the food chain for all animal life in the oceans. According to a popular theory, a darkening of a similar magnitude as a result of dust created by the impact of a large extraterrestrial body with the Earth caused the massive extinctions

which took place at the cretaceous-tertiary boundary about 65 million years ago.

Long-term climate changes are also possible as a result of a nuclear war. These, however, are even more difficult to access. While the dark aerosol suspended in the atmosphere would change the heat and radiative balance and dynamics of the Earth and the atmosphere for awhile, longer lasting effects may result from changes in the reflective properties of the Earth due to the fires and soot deposition. For example, it may be possible that the deposition of soot on Arctic snow and ice would lead to such heavy snow and ice melting as to trigger a climate change.

I have described to you the atmospheric effects that we have thus far identified as potentially important. Much more detail may be found in our Ambio article. Most of these effects are quite complex and difficult to model.

In our example calculations we have not tried to exaggerate the effects, but only to show the least of what might happen following a nuclear war. It is our hope that our study will provide an introduction to a more thorough analysis of this important problem, and that a better understanding of the consequences of a nuclear war will help to deter such an atrocity.

Thank you.

[The prepared statement of Professor Birks follows:]

Atmospheric Effects of a Nuclear War

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Testimony Presented To

**House Committee on Science and Technology
Investigative and Oversight Subcommittee**

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Introduction

What effects, if any, would a nuclear war have on the earth's atmosphere? This is a question which Paul Crutzen and I began to address approximately one year ago as part of a study sponsored by the Royal Swedish Academy of Sciences. Scientists from both East and West were asked to contribute articles evaluating as best possible the effects of a nuclear war on the oceans, the atmosphere, agriculture, global supplies of food and freshwater, human behavior, and the global economic consequences. The results of these studies, including our findings for the atmosphere, were published in June of this year in a special issue of the Swedish environmental journal *Ambio*. Here I would like to summarize our results for you.

Nuclear War Scenario. Any study of possible nuclear war effects must begin with some assumptions concerning the numbers and sizes of nuclear weapons detonated and the locations of the targets for those weapons. Our evaluation of the atmospheric effects of a nuclear war is based on a scenario provided by a panel of advisors for the *Ambio* study. The scenario is neither the least nor the worst of what might happen in a nuclear war. Targets are assigned to only 14,737 of the approximately 59,000 tactical and strategic warheads expected to be in existence in 1985. These targets include nearly all cities in the Northern Hemisphere having populations greater than 100,000, missile silos, military installations of all sorts, industrial complexes, oil and gas fields and refineries, energy stockpiles, chemical plants, hydroelectric stations, and a variety of other economic and military targets. In terms of total explosive energy, these targets utilize 5,742 Mt, or less than half of that available in the nuclear arsenals of the United States and the Soviet Union.

Fires

In consideration of what these thousands of nuclear explosions would do to the atmosphere, our attention was drawn to the many fires that would result. To begin with, much of the damage caused by a nuclear explosion is a result of fire. For example, following the relatively small nuclear explosion above Hiroshima, fire consumed every combustible object within two kilometers of the hypocenter. During a nuclear war it would not be possible to extinguish fires because of nuclear contamination, loss of water lines and fire-fighting equipment and perhaps most importantly -- loss of people. Besides the fires in urban and industrial centers, we expect that vast forest fires would start, extensive grasslands and agricultural fields would burn, and it is likely that many natural gas and oil wells would be ruptured, releasing huge quantities of oil and gas, much of which would also burn. In our estimation, the most serious atmospheric effects of a nuclear war would result from these many fires.

Forest Fires. As an example of how these fires could affect the earth's atmosphere, we have taken forest fires into special consideration. It is difficult to estimate how much forest area might burn as a result of a nuclear exchange. For the purposes of our study we assumed that a total area of one million square kilometers or about 380,000 square miles of forest area spread around in the northern hemisphere would be consumed by wildfires. This is probably an underestimate, as it is only 20 times larger than what is now annually consumed by wildfires, amounts to only 4% of the temperate and boreal forest lands, and is not larger than the combined urban areas. The U.S. Forest Service has estimated that a nuclear attack on the U.S. of approximately 1,500 Mt would burn a land area of between 400,000 and 6,000,000 square kilometers in the U.S. alone. Thus, our estimate of 1,000,000 square kilometers throughout the Northern Hemisphere is low in comparison.

Screening of Sunlight by Smoke. Where there is fire there is smoke. Based on measurements of particulate matter produced by forest fires, we estimate that the burning of 1,000,000 square kilometers of forest would inject between 200 and 400 million tons of particulate matter into the atmosphere. Because of their small size, the residence time of smoke particles coming from forest fires is about 5-10 days. These particles are strong absorbers of sunlight and infrared radiation. If we assume that the forest fires will last for two months, a spread of 200 to 400 million tons of aerosol over half of the Northern Hemisphere would cause an average particle loading such that the integrated vertical column of particles is equal to 0.1 to 0.5 grams per square meter. As a result, the amount of sunlight reaching the surface of the earth would be reduced by a factor between 2 and 150 at noontime in the summer. These reduction factors would be larger during other seasons and during other times of day. Thus, it is quite possible that for several weeks following a nuclear war more than 99% of the sunlight would be blocked for much of the Northern Hemisphere.

This estimate is based only on forest fires. Large forest fires in arctic regions are commonly accompanied by fires in peat bogs, which may burn over two meters in depth. The production of aerosol by such fires has not been included in this estimate, nor does this estimate include contributions from combustion in cities, industrial centers or oil and gas wells. It is possible that particulate matter produced in very hot fires such as those that would rage in cities and in oil and gas fields would be injected to very high altitudes so that the atmospheric residence time would be much longer than the 5-10 days applied to the forest fire calculations. In the stratosphere, for example, the residence time for particulate matter is of the order of years. A longer residence time for the smoke particles in the atmosphere would both prolong the darkening effect and increase its magnitude. The screening of sunlight by smoke has not been considered in previous studies of nuclear war effects. We believe this finding to be the most significant result of our study.

Photochemical Smog Formation.

Besides shrouding the earth with a dark smoke layer, it is also possible that the thousands of fires would cause a severe photochemical smog to develop. The ingredients of smog are oxides of nitrogen, hydrocarbons and sunlight. Because light is required, the photochemical smog can only develop once the fires cease to burn and the smoke begins to be removed from the atmosphere. The oxides of nitrogen necessary for smog formation are provided both by the nuclear explosions themselves and by the fires. Nuclear explosions produce nitrogen oxides by heating air to very high temperatures. The explosion of 5,742 Mt of nuclear weapons would introduce about 13.4 million tons of nitrogen oxides (measured as nitrogen) to the atmosphere. Because of forest fires, we estimate an input of another 15-30 million tons of nitrogen oxides. Other atmospheric inputs from forest fires include 200-400 million tons of carbon monoxide (measured as carbon) and tens of millions of tons of reactive hydrocarbons, mostly ethylene and propylene, important ingredients in photochemical smog formation.

Natural gas and oil fields were among the major targets of the nuclear war scenario we were asked to evaluate. Although it is not possible to target all of the more than 800,000 gas and oil wells in the world, certain areas where production is both high and concentrated are likely targets of a nuclear war. Saudi Arabia's 800 oil wells, for example, outproduce the United States' 590,000 oil wells. Furthermore, many gas and oil wells are under high pressure and when ruptured would release gas and oil at rates much higher than when under control and in production. It would take fewer than 300 breakages of the magnitude of the famous gaswell blowout at Gassi Touil in the Sahara to release natural gas at the current rate of world-wide consumption. Known as the "Devil's Cigarette Lighter", this well powered a 200-meter high flame with 15 million cubic meters of gas per day until it was capped.

For the purposes of our model calculations we assumed that oil and natural gas would be released and burned at a rate equal to current consumption. Furthermore, we assumed that 25% of the natural gas would be released unburned. The methane, and especially the ethane and propane because of their high reactivity in the atmosphere, contributed significantly to the photochemical smog formation.

Using these illustrative assumptions, we modeled the photochemistry following a nuclear war. Our calculations show that in the Northern Hemisphere levels of ozone at the ground would increase from 30 ppbv (parts per billion by volume) in the present atmosphere to levels approaching 160 ppbv for some months following the war. These calculations are for latitudinal averages, and since the fires occur on land, we expect that ozone levels over land would be greater than 160 ppbv and over oceans would be less. With time, substantial increases in other pollutants such as the strong phytotoxicant, peroxyacetyl nitrate or "PAN" to several ppbv may also occur.

We would like to emphasize that this is only an example of what might occur as a result of a nuclear war. The formation of photochemical smog is complicated by the the presence of the fire-produced aerosol. It is possible that the smoke particles would adsorb some fraction of the oxides of nitrogen and thus partially cleanse the atmosphere of this pollutant. The amount of smog formation is also highly dependent on the quantities of hydrocarbons released as a result of the breakage of natural gas wells, which may be more or less than what we have used in our example. Also, we have not included atmospheric inputs from the fires in cities. Between 5 and 15% of the world's oil production goes into the manufacture of high polymers. Considering that most of these materials are stored in cities and assuming a lifetime of ten years for such materials before disposal, we may estimate that there is roughly a years production of petroleum stored in cities as plastics and other polymers. There is, of course, an enormous quantity of lumber and wood products stored in cities as well as a non-negligible amount of asphalt in the streets. The combustion of all of these materials would certainly contribute to both the smoke production and to the oxides of nitrogen and reactive hydrocarbons necessary to photochemical smog formation.

Ozone Shield Depletion

Past studies of the atmospheric effects of a nuclear war, such as the U.S. National Academy of Sciences study of 1975, have emphasized primarily the effects of nuclear explosions on the stratospheric ozone layer. Whereas ozone is undesirable at the ground level because of its toxicity to both animals and plants, ozone in the stratosphere (~12-50 km altitude) provides a protective shield against harmful ultraviolet radiation from the sun. Although oxides of nitrogen tend to cause ozone levels in the lower atmosphere to increase, in the upper atmosphere where the chemical composition and light spectrum are quite different, nitrogen oxides act as a catalyst for ozone destruction.

Our model does not predict significant ozone depletion in the stratosphere for *Ambio's* 5,742 Mt nuclear war scenario. This is because very few weapons having yields greater than 1 Mt are used in this scenario. Only explosions having yields greater than 1 Mt result in fireballs that rise into and stabilize in the stratosphere. For comparison with previous studies, we also evaluated the effects of a second nuclear war scenario. This scenario considers a 10,000 Mt war in which the weapon yields are distributed equally between 1-Mt and 10-Mt weapons (i.e. 5000 1-Mt and 500 10-Mt explosions). This scenario resulted in an initial depletion of the ozone column of greater than 50% throughout most of the northern hemisphere with an exponential recovery time of about three years, in good agreement with past studies. Thus, should the United States and Soviet Union choose to use larger yield weapons, large reductions in the protective ozone shield are to be expected. This would result in an increase by several fold of the biologically damaging

ultraviolet radiation reaching the earth's surface.

There are other mechanisms by which the oxides of nitrogen produced by the nuclear explosions and fires might be injected into the stratosphere. For example, it is possible that enormous fires in cities or in oil gas fields could produce plumes of hot air that penetrate the tropopause and carry oxides of nitrogen into the stratosphere. Another possibility is that the heating of the troposphere due to the absorption of sunlight by suspended particulate matter would result in a change in the dynamical structure of the atmosphere such that tropospheric air containing nitrogen oxides would be mixed into the stratosphere and thereby cause ozone depletion.

Conclusions

For many weeks following a nuclear war the atmosphere would be loaded with particulate matter to such an extent that the amount of sunlight reaching the surface of the earth would be substantially reduced. It is quite possible that greater than 99% of the sunlight would be blocked during this time. As the fires subside and the particulate matter is deposited, it is likely that a severe photochemical smog situation would develop throughout the northern hemisphere and persist for several more weeks. Because of the reduced sunlight and damage by air pollutants such as ozone and PAN, it is unlikely that there would be any significant yield of food crops during the first year following a nuclear war if the war occurs during the growing season. Additional damage to food crops by solar ultraviolet radiation would result if the stratospheric ozone shield is also reduced.

These atmospheric changes would also have important human health effects, and such effects would be in synergism with radiation exposure, lack of adequate food supplies and lack of medical care. The darkened sky would undoubtedly add to the psychological stress of the initial survivors.

The atmospheric effects of a nuclear war would damage many natural ecosystems. For example, it is possible that most of the phytoplankton and herbivorous zooplankton in more than half of the northern hemisphere oceans would die as a result of the darkening by fire-produced aerosol. Phytoplankton are microscopic green plants that begin the food chain for all animal life in the oceans. According to a popular theory, a darkening of a similar magnitude as the result of dust created by the impact of a large extraterrestrial body with the earth caused the massive extinctions which took place at the Cretaceous-Tertiary boundary about 65 million years ago.

Long-term climate changes are also possible as a result of a nuclear war. These, however, are even more difficult to assess. While the dark aerosol suspended in the atmosphere would change the heat and radiative balance and dynamics of the earth and the atmosphere for awhile, longer lasting effects may result from changes in the reflective

properties of the earth due to the fires and soot deposition. For example, it may be possible that the deposition of soot on arctic snow and ice would lead to such heavy snow and ice melting as to trigger a climate change.

I have described to you the atmospheric effects that we have thus far identified as potentially important. Much more detail may be found in our *Ambio* article (Volume XI, Number 2-3, pp 114-125, 1982). Most of these effects are quite complex and difficult to model. In our example calculations we have not tried to exaggerate the effects, but only to show the least of what might happen following a nuclear war. It is our hope that our study will provide an introduction to a more thorough analysis of this important problem, and that a better understanding of the consequences of a nuclear war will help to deter such an atrocity.

John William Birks**Biographical Information**

John W. Birks is an Associate Professor in the Department of Chemistry and a Fellow of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado in Boulder, Colorado. He earned his B.S. degree in chemistry at the University of Arkansas in 1968 and his Ph.D. in chemistry at the University of California at Berkeley in 1974. From 1974 to 1977 he was an Assistant Professor at the University of Illinois at Urbana-Champaign. Since that time he has been on the faculty of the University of Colorado.

Professor Birks' principal research interest is in the area of atmospheric chemistry. Much of his work has been devoted to laboratory studies of chemical reactions that regulate the quantity and distribution of ozone in the stratosphere with particular emphasis on the projected impact of the use of aerosol spray cans on the ozone shield. His interest in nuclear war effects began in 1972 when he co-authored a paper with Harold Johnston and Gary Whitten on the effects of nuclear explosions on stratospheric nitric oxide and ozone. This paper analyzed the effects of past atmospheric tests of nuclear weapons on the ozone layer.

During the past year, while on sabbatical leave from the University of Colorado, Professor Birks collaborated with Paul Crutzen at the Max Planck Institute for Chemistry in Mainz, West Germany on a study of the atmospheric effects of a nuclear war. This study was sponsored by the Royal Swedish Academy of Sciences and is published in the June issue of *Ambio* (Vol. XI, Number 2-3, 1982). Paul Crutzen is Director of the Air Chemistry Division of the Max Planck Institute and is former Director of the Air Quality Division of the National Center for Atmospheric Research in Boulder, Colorado.

The written testimony presented here by Dr. Birks was prepared jointly with Dr. Crutzen.

Mr. SHAMANSKY. Thank you, Professor Birks.

Professor Westing, are you going to paraphrase your testimony, or submit your statement and just comment on it, or read it?

Professor WESTING. I had intended to read the bulk of it, yes.

Mr. SHAMANSKY. Fine. Again, the reason I ask that question, shortly I have to leave. We are only scheduled in two or three places at the same time. It is very difficult to do. I don't want to keep you waiting.

How long is your testimony?

Professor WESTING. About 7 or 8 minutes.

Mr. SHAMANSKY. All right, why don't you begin? I am interested in listening to your testimony.

Professor WESTING. I must begin by thanking you for this opportunity to testify on a subject of such grave importance to all of us, and to stress as well that I leave to others, including, of course, Drs. Geiger, Abrams, and Pitts, the truly horrible effects of nuclear war on humans, per se; that is, the medical, psychological, and societal effects.

Fortunately, the Earth has yet to witness a large-scale nuclear war, with its immense and diverse energy releases, so that predictions of environmental impact must be to a considerable extent speculative, as was already mentioned earlier by Dr. Drell, and I think it will be mentioned by Dr. Von Hippel.

The difficulties of such predictions are compounded by not knowing the total numbers, types, yields, and locations of the nuclear detonations in a possible major war between the superpowers. Nevertheless, studies of our Hiroshima and Nagasaki attacks, of our numerous test explosions, of natural catastrophes, and of theoretical considerations permit us to at least suggest the possible extent of environmental impact of such an event.

The energy releases of primary environmental concern are blast, heat, and nuclear radiation. I shall devote brief space to each of these in turn before discussing some of the potential second-order effects of ecological concern.

A nuclear bomb dissipates roughly half or more of its tremendous energy in the form of a shock or blast wave. The blast is responsible for much of the immediate physical damage brought about by nuclear explosions. Thus, a single 1-megaton airburst would knock down virtually all of the trees over some 35,000 acres. It would additionally force thousands of tons of the water vapor, the humidity, present in the lower atmosphere into the upper atmosphere. On the other hand, a single 1-megaton ground burst would blast out a huge crater, extending over perhaps 30 acres, and with a maximum depth of some 300 feet.

An estimated 500,000 tons of the rock and soil thus displaced would be hurled into the upper atmosphere as a fine dust. A single 1-megaton underwater burst would lift tens of thousands of tons of water aerosol and vapor into the upper atmosphere.

A nuclear bomb dissipates roughly another third or more of its energy in the form of an intense thermal or heat wave. This heat would initiate wildfires over an immense area, the exact size depending, of course, upon the weather conditions at the time, the terrain, and the nature of the vegetative cover. Indeed, under cer-

tain terrain and fuel conditions these fires would coalesce into a truly infernal firestorm.

On a clear, dry summer day a single 1-megaton airburst might well initiate wildfires throughout an area of more than 80,000 acres, and these are likely to continue to burn and spread for weeks. These fires would wreak havoc among the plants and animals surviving the blast and nuclear radiation. They would also inject immense amounts of smoke into the atmosphere. The surface disruption from blast and fire would in turn lead to massive site degradation of long duration; that is, decades, from soil erosion and nutrient losses in solution—so-called nutrient dumping. Moreover, the exceedingly high temperatures momentarily generated by a single 1-megaton airburst would result in the transformation of some 5,000 tons of the atmosphere into various oxides of nitrogen. These oxides of nitrogen would in turn produce a smog in the lower atmosphere and would degrade the ozone in the upper atmosphere, a molecule that forms a protective barrier against excessive solar ultraviolet radiation.

A nuclear bomb dissipates the remaining 10 percent or so of its energy in the form of nuclear radiation, a portion of which is released as an initial burst, and the remainder—in the form of radioactive fallout—much more slowly and widely. A single 1-megaton ground burst would present a lethal dosage of nuclear radiation to all exposed vertebrates—including, of course, humans and livestock—over about 90,000 acres.

As a specific example, I might cite our Bravo test at Bikini on March 1, 1954, a single 15-megaton ground burst which deposited a lethal level of fallout over an area approximately the size of my State of Massachusetts. Moreover, although our test program on Bikini ended more than a quarter of a century ago, the island remains uninhabitable despite intensive cleanup attempts.

I should mention the Arms Control and Disarmament Agency recently estimated that the conditions still prevailing on Bikini would prevail over a third of the Soviet Union and thus presumably over at least a third of the United States after a war.

I should also note here that in a war some of the hundreds of stationary or mobile reactors, nuclear reactors and the like, will be hit and the thereby dispersed radioactive debris will increase the extent of the regions of death to flora and fauna and of uninhabitability to humans.

The several forms of intense energy released during a nuclear war that I have just summarized would leave large areas of appalling devastation to man and nature even from single or small numbers of nuclear detonations. However, I wish to devote the remainder of this presentation to the possibility that a large-scale exchange of nuclear weapons could result in longer term synergistic second-order effects of the biosphere.

Thus, the total effect of many bombs will almost certainly be greater and more multifarious than a mere summation of the effects of each individual bomb would suggest. And, moreover, some of these effects are sure to come upon us as a surprise.

Among the potentially disastrous phenomena that we can guess at would be those set in motion by the large-scale injection of fine particles of dust and water into the upper atmosphere, by the gen-

eration of vast quantities of smoke and smog, to which we have been alerted by Professor Birks, and by the introduction of huge amounts of oxides of nitrogen into the ozone layer. The first, dust and water in the stratosphere, could have a long-term adverse effect on our climate; the second, smoke and smog in the troposphere could for a time, for perhaps one or even two growing seasons, substantially reduce the primary productivity of the ecosystems and debilitate our agriculture; and the third, diminishing the ozone layer could permit damaging ultraviolet radiation to reach the Earth's surface, as I will develop more fully below.

It is not at all certain either how much of the protective ozone layer would be destroyed by a large-scale nuclear war, or how long it would take for the ozone layer to return to its normal state of equilibrium. One major study carried out by Professor Friend and his colleagues on behalf of the National Academy of Sciences suggested that of the order of half, that is, somewhere between 30 percent and 70 percent, of the ozone would be destroyed, and that substantial recovery would take up to a decade.

More recent, as yet unpublished, estimates at the Massachusetts Institute of Technology suggest that these values might well be optimistic. I understand these will be entered into the record by Professor Tsipis. However, the uncertainties involved are so intractable, both as regards the input data and the models, that it becomes almost silly to argue over the magnitude of these values—at least their precise values.

Using a 50-percent depletion of several years' duration as our starting point, we find that this will lead to a substantially increased fraction of solar ultraviolet radiation to reach the Earth's surface—perhaps a threefold increase in the biologically active portion, which is in the wavelength range of approximately 280 to 380 nanometers, the so-called UV-B range. It must be added here that this effect will be worldwide, even if the war should be confined to portions of the Northern Hemisphere, owing to the worldwide lateral dispersion by diffusion of the ozone layer in the stratosphere.

This hasn't been mentioned in the earlier testimony. It has always been an emphasis on the Northern Hemisphere. But even if the war is in the Northern Hemisphere, stratospheric distribution is not by turbulence but by diffusion, so it will go around the whole world.

The ecological impact of enhanced UV-B radiation on various natural and artificial ecosystems—oceanic, terrestrial, agricultural—cannot be predicted with any certainty, but could be devastating on a global basis.

Earlier it was asked by Mr. Shamansky who would eat the food. The problem is, these ozone effects are worldwide and there are an awful lot of people in places that will not be directly involved in the war.

Oceanic ecosystems would be substantially disrupted on a global basis by the enhanced UV-B radiation following a large-scale nuclear exchange. Marine plankton lie close to the surface of the ocean, and if they were killed off to a substantial extent, which is a distinct possibility, the oceanic food chain would be largely broken and the fish stocks which depend upon this chain placed in jeopardy.

Since the ozone effect is global, and adds to that of the pall of smoke and smog, repopulation might take a number of years and would thus be unlikely to be rapid enough to save a major fraction of the many plankton-dependent species. The restoration of fish stocks throughout the world, both commercial and otherwise, might thus in turn take many years to occur.

Terrestrial ecosystems would also be substantially disrupted on a global basis by the enhanced UV-B radiation following a large-scale nuclear exchange. This is so because it can be extrapolated from the limited available information that perhaps as many as 20 percent of the plant species might succumb directly or indirectly and an additional fraction of them would have their photosynthesis, their food production, and growth impaired.

These debilitations add, of course, to those of nuclear radiation from fallout, especially so in the case of the relatively sensitive conifer ecosystems, of smoke and smog, and so forth. Such drastic perturbations among the primary producers of the world's ecosystems would in turn exert a substantial impact on the wildlife throughout the world depending upon them. Some of the animal life might also be injured directly by the enhanced UV-B radiation. This is so because in most instances the newly created damaging levels would not be detectable by the animals and would thus preclude evasive actions. Thus, for example, unavoidable damage to the cornea of the eye—obvious from the remarks of Professor Pitts—would reduce the efficiency of hawks, eagles, and much other wildlife in their hunting or foraging abilities.

Agricultural ecosystems during the first several years following a major nuclear exchange would also be severely disrupted on a global basis by the enhanced UV-B radiation. Again, such damage would compound the problems resulting from radioactive contamination—to which I should add the crops are generally more sensitive than their weed competitors and their fungal and insect pests—the smoke and smog pall, which would reduce productivity both directly and perhaps via adverse climatic changes, as noted by Professor Friend, and the paucity of farmworkers, of implements, of fuel, of fertilizers and of pesticides such as herbicides, fungicides, and insecticides. Some crops, among them corn, sugar beets, tomatoes, beans and peas, turn out to be especially sensitive to enhanced UV-B radiation, and livestock would develop debilitating corneal and perhaps skin lesions.

In conclusion, it is important for me to stress that my outline of the potential environmental consequences of nuclear warfare are based upon extrapolations from very limited data. My predictions were meant to be conservative ones and thus probably err on the side of optimism.

For example, the several diverse impacts discussed separately above would, of course, occur simultaneously and, by reinforcing each other, would be likely to have effects substantially greater than if they had occurred separately.

Synergism of this kind is most difficult to predict. I wish to additionally stress that even any single major environmental or ecological perturbation could result in entirely unforeseen ramifications. It is instructive to note here that the potential dangers of enhanced ultraviolet radiation resulting from nuclear war had not been fore-

seen by military planners but were recognized accidentally as the result of an unrelated study of supersonic aircraft exhausts. Indeed, if total nuclear war were ever to occur, it would be unrealistic for me to rule out at least the possibility that the impact on the biosphere would be sufficiently drastic to lead to the ultimate extinction of the human species.

[The prepared statement of Dr. Westing follows:]

ENVIRONMENTAL CONSEQUENCES OF NUCLEAR WARFARE

Arthur H. Westing, M.F., Ph.D.

Testimony before the U.S. House of Representatives, Committee on Science and Technology, Subcommittee on Investigations and Oversight (Albert Gore, Jr., Chairman), Washington, 15 September 1982.

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The earth has yet to witness a large-scale nuclear war, with its immense and diverse energy releases, so that predictions of environmental impact must be to a considerable extent speculative. The difficulties of such predictions are compounded by not knowing the total numbers, types, yields, and locations of the nuclear detonations in a possible major war between the superpowers. Nevertheless, studies of our Hiroshima and Nagasaki attacks, of our numerous test explosions, of natural catastrophes, and of theoretical considerations permit us to at least suggest the possible extent of environmental impact of such an event (ACDA, 1978; Nier et al., 1975; Thunborg et al., 1981; Westing, 1977; 1978; 1981; 1982).

The energy releases of primary environmental concern are blast, heat, and nuclear radiation. I shall devote brief space to each of these in turn before discussing some of the potential second-order effects of ecological concern.

A nuclear bomb dissipates roughly half or more of its tremendous energy in the form of a shock or blast wave. The blast is responsible for much of the immediate physical damage brought about by nuclear explosions. Thus a single one-megaton airburst would knock down virtually all of the trees over some 35,000 acres. It would additionally force thousands of tons of the water vapor (humidity) present in the lower atmosphere (troposphere) into the upper atmosphere (stratosphere). On the other hand, a single one-megaton groundburst would blast out a huge crater, extending over perhaps 30 acres and with a maximum depth of some 300 feet. An estimated 50,000 tons of the

rock and soil thus displaced would be hurled into the upper atmosphere as a fine dust. A single one-megaton underwater burst would lift tens of thousands of tons of water aerosol and vapor into the upper atmosphere.

A nuclear bomb dissipates roughly another third or more of its energy in the form of an intense thermal or heat wave. This heat would initiate wildfires over an immense area, the exact size depending, of course, upon the weather conditions at the time, the terrain, and the nature of the vegetative cover. Indeed, under certain terrain and fuel conditions these fires would coalesce into a truly infernal firestorm. On a clear, dry summer day a single one-megaton airburst might well initiate wildfires throughout an area of more than 80,000 acres, and these are likely to continue to burn and spread for weeks. These fires would wreak havoc among the plants and animals surviving the blast and nuclear radiation. They would also inject immense amounts of smoke into the atmosphere. The surface disruption from blast and fire would in turn lead to massive site degradation of long duration (i.e., decades) from soil erosion and nutrient losses in solution (so-called nutrient dumping). Moreover, the exceedingly high temperatures momentarily generated by a single one-megaton airburst would result in the transformation of some 5,000 tons of the atmosphere into various oxides of nitrogen. These oxides of nitrogen would in turn produce a smog in the lower atmosphere and would degrade the ozone in the upper atmosphere, a molecule that forms a protective barrier against excessive solar ultraviolet radiation.

A nuclear bomb dissipates the remaining 10% or so of its energy in the form of nuclear radiation, a portion of which is released as an initial burst and the remainder--in the form of radioactive fallout--much more slowly and widely. A single one-megaton groundburst would present a lethal dosage of nuclear radiation to all exposed vertebrates (including, of course, humans and livestock) over about 90,000 acres. As a specific example I might cite our 'Bravo' test at Bikini on 1 March 1954--a single 15-megaton groundburst--which deposited a lethal level of fallout over an area approximately the size of my State of Massachusetts. Moreover, although our test program on Bikini ended more than a quarter of a century ago, the island remains uninhabitable despite intensive cleanup attempts. It must also be noted here that in a war some of the hundreds of stationary or mobile (naval) reactors and the like

will be hit and the thereby dispersed radioactive debris will increase the extent of the regions of death to flora and fauna and of uninhabitability to humans.

The several forms of intense energy released during a nuclear war that I have just summarized would leave large areas of appalling devastation to man and nature even from single or small numbers of nuclear detonations. However, I wish to devote the remainder of this presentation to the possibility that a large-scale exchange of nuclear weapons could result in longer term synergistic second-order effects on the biosphere. Thus, the total effect of many bombs will almost certainly be greater and more multifarious than a mere summation of the effects of each individual bomb would suggest; and, moreover, some of these effects are sure to come upon us as a surprise. Among the potentially disastrous phenomena that we can guess at would be those set in motion by the large-scale injection of fine particles of dust and water into the upper atmosphere, by the generation of vast quantities of smoke and smog, and by the introduction of huge amounts of oxides of nitrogen into the dust and water in the stratosphere, ozone layer. The first, could have long-term adverse effects on our climate (Nier et al., 1975), the second, could for a time (i.e., for perhaps one or even two growing seasons) substantially reduce the primary productivity of ecosystems and debilitate our agriculture (Crutzen & Birks, 1982), and the third, a depleted ozone layer, could permit damaging ultraviolet radiation to reach the earth's surface, as developed more fully below.

It is not at all certain either how much of the protective ozone layer would be destroyed by a large-scale nuclear war or how long it would take for the ozone layer to return to its normal state of equilibrium. One major study carried out several years ago by the National Academy of Sciences suggested that of the order of half (30% to 70%) of the ozone would be destroyed and that substantial recovery would take up to a decade (Nier et al., 1975). More recent as yet unpublished estimates at the Massachusetts Institute of Technology suggest that these values might well be optimistic (Kosta Tsipis, pers. commun., Apr 82). However, the uncertainties involved are so intractable (both as regards the input data and the models) that it becomes almost silly to argue over the magnitude of these values. Using a 50% depletion of several years' duration as our starting point, we find that this will lead to a

substantially increased fraction of solar ultraviolet radiation to reach the earth's surface--perhaps a three-fold increase in the biologically active portion, which is in the wavelength range of approximately 280-380 nanometers, the so-called UV-B range (Gerstl et al., 1981). It must be added here that this effect will be worldwide even if the war should be confined to portions of the northern hemisphere owing to the worldwide lateral dispersion by diffusion of the ozone layer in the lower stratosphere.

The ecological impact of enhanced UV-B radiation on various natural and artificial ecosystems--oceanic, terrestrial, agricultural--cannot be predicted with any certainty, but could be devastating on a global basis (Crutzen & Birks, 1982; Kruger et al., 1982; Nier et al., 1975; Tukey et al., 1979).

Oceanic ecosystems would be substantially disrupted ^{on a global basis} by the enhanced UV-B radiation following a large-scale nuclear exchange (Calkins & Thordardottir, 1980; Jokiel, 1980; ^{Kruger et al., 1982;} Tukey et al., 1979; Worrest et al., 1981a; 1981b). Marine plankton lie close to the surface of the ocean and if they were killed off to a substantial extent, the oceanic food chain would be largely broken and the fish stocks which depend upon this chain placed in jeopardy. Since the ozone effect is global (and adds to that of the pall of smoke and smog) repopulation might take a number of years, and would thus be unlikely to be rapid enough to save a major fraction of the many plankton-dependent species. The restoration of fish stocks ^{throughout the world} (both commercial and otherwise) might thus in turn take many years to occur.

Terrestrial ecosystems would also be substantially disrupted ^{global basis} on a ^{by the} enhanced UV-B radiation following a large-scale nuclear exchange (Caldwell, 1981; Faber et al., 1979; ^{Kruger et al., 1982;} Nier et al., 1975; Tukey et al., 1979). This is so because it can be extrapolated from the limited available information that perhaps as many as 20% of the plant species might succumb directly or indirectly, and an additional fraction of them would have their photosynthesis (food production) and growth impaired. And these debilitations add, of course, to those of nuclear radiation from fallout (especially so in the case of the relatively sensitive conifer ecosystems), of smoke and smog, and so forth. Such drastic perturbations among the primary producers of the world's ecosystems (including newly altered relationships of competitive advantage) would in turn exert a substantial impact on the wildlife throughout the world depending upon

them. Some of the animal life might also be injured directly by the enhanced UV-B radiation. This is so because in most instances the newly created damaging levels would not be detectable by the animals^{and would therefore preclude evasive actions.} Thus, for example, unavoidable damage to the cornea of the eye would reduce the efficiency of hawks, eagles, and much other wildlife in their hunting or foraging abilities.

Agricultural^{ecosystems} during the first several years following a major nuclear exchange would also be severely disrupted on a global basis by the enhanced UV-B radiation (ACDA, 1978; ^{Kruger et al., 1982;} Nier et al., 1975; Tukey et al., 1979). And again, such damage would compound the problems resulting from radioactive contamination (to which crops, for example, are generally more sensitive than their weed competitors and their fungal and insect pests), the smoke and smog pall (which would reduce productivity both directly and perhaps via adverse climatic changes), and the paucity of farm workers, implements, fuel, fertilizers, and pesticides (herbicides, fungicides, insecticides). Some crops--among them corn, sugar beets, tomatoes, beans, and peas--turn out to be especially sensitive to enhanced UV-B radiation, and livestock would develop debilitating corneal and perhaps skin lesions.

In conclusion, it is important for me to stress that my outline of the potential environmental consequences of nuclear warfare are based upon extrapolations from very limited data. My predictions were meant to be conservative ones and thus probably err on the side of optimism. For example, the several diverse impacts discussed separately above would, of course, occur simultaneously and, by reinforcing each other, would be likely to have effects substantially greater than if they had occurred separately. Synergism of this kind is most difficult to predict. I wish to additionally stress that even any single major environmental or ecological perturbation could result in entirely unforeseen ramifications. It is instructive to note here that the potential dangers of enhanced ultraviolet radiation resulting from nuclear war had not been foreseen by military planners, but were recognized accidentally as the result of an unrelated study of supersonic aircraft exhausts. Indeed, if total nuclear war were ever to occur, it would be unrealistic for me to rule out at least the possibility that the impact on the biosphere would be sufficiently drastic to lead to the ultimate extinction of the human species.

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Mr. VOLKMER [presiding]. Thank you. I have several questions here, and if the staff has any additional, we will go on with those.

Dr. Friend, as I understand the scenario you assumed, it would be in the order of 10 to 12,000 megatons, is that correct?

Professor FRIEND. 13,000.

Mr. VOLKMER. Now, what ozone effects might be felt, let's say, at a lower level of megatonnage, say half that amount?

Professor FRIEND. It is difficult without doing the calculations in detail, to give you an answer straight off. It is not what we call a linear effect. If you cut the yield in half, you don't cut the ozone destruction in half.

You can take some estimate of what is going on by looking at Professor Birks' calculations. The models are somewhat similar.

Mr. VOLKMER. This is addressed to you, or Dr. Birks. Were the ozone layer to be depleted as a result of nuclear war, when would the depletion effect be at its worst?

Professor FRIEND. I guess we both have answers to that.

Mr. VOLKMER. That's what I would like to find out.

Professor FRIEND. It happens relatively rapidly within the first month or two, I believe is the way it would come out, using the kinds of models we now have. However they cannot reliably predict worldwide effects occurring on such short time scales. But I think, because it is a worldwide effect, we aren't able to say accurately, for something that occurs that rapidly, what it would be. I would estimate conservatively within 6 months.

Mr. VOLKMER. Assume that only targets in the U.S.S.R. and maybe Eastern Europe, parts of Western Europe and the United States, and maybe some parts of Canada were targeted. How would such a war affect the ozone layer say, in South Africa or Chile or Argentina?

Professor FRIEND. In the National Academy study that we did in 1975, we made estimates for the Northern Hemisphere and for the global average. The average for the globe followed the depletion and recovery schedule more or less the way the Northern Hemisphere did. If we had done the calculation in more detail, we would have found the Southern Hemisphere lagged behind the Northern Hemisphere by some months.

The average for the world turned out to be about half for the main depletion, and it turned out to be about half that for the Northern Hemisphere, which means that the Southern Hemisphere is going to be somewhat less affected by maybe a factor of 3 or so than the Northern Hemisphere.

Mr. VOLKMER. Do you have any views regarding long-term ecological and climatic consequences of ozone depletion?

Professor FRIEND. Well, you have heard testimony from the biological people. For the atmosphere, it takes 2 years after the peak to get back to half of the ozone, to restore the ozone back to one-half the maximum depletion that occurred. So within about 4 or 5 years we are back practically to pre-existing conditions just for the atmospheric composition.

Now, in terms of the climate, as I mentioned in my testimony, the straightforward calculations that we can make now, very crude, estimate effects of the order of half a degree or so Celsius cooling around the world that would last for a period of a year or

two. Those are crude estimates, based on relatively crude models, but we cannot be sure that we could not have induced a permanent climate shift because we don't know the nature of climate as such to preclude that possibility.

Mr. VOLKMER. Do we have any historical analog that we can use to predict the magnitude of this?

Professor FRIEND. Based on actual data, no. No experiment like this has occurred from the point of view of compositional changes all around the world. However, for the effects of putting particles into the stratosphere, historically we have precedence for that. Large, explosive volcanos do cause loadings of the stratosphere of about the order that we anticipated would occur from even this 10- or 13,000-megaton nuclear weapon. Those effects are about this one-half a degree Celsius average around the world, the temperature lowering. That has occurred a few times during the history of world recordkeeping.

Mr. VOLKMER. Just as an aside, my people keep wondering whether the volcanic ash from the eruption in Mexico is affecting weather conditions in that immediate vicinity.

Professor FRIEND. That is a question often asked in the press, too, nowadays, and the answer is we can't be sure that the changes or weather effects that we are seeing now are, in fact, due to the volcano. But undoubtedly, there will be some effect noticeable when we do ex post factor analyses of the global climate records.

Mr. OSTROV. You have mentioned that there are no real historical analogs for some of these problems. One of the questions that we have is whether additional experimentation will yield additional answers in these areas. What if funding were available? Also, if it were possible to convene an international symposium, perhaps at an official level, would such a convocation of scientific experts produce additional answers in these areas? If such a forum were to take place, what means would you see for conveying the answers from such a forum to world leaders who were in a position to act on such information and perhaps integrate it into decisions that are now taking place?

Professor FRIEND. That's a tough question in a sense. In this field there are so many things, the uncertainty ranges are so large, that it is hard to foresee exactly what will change our knowledge qualitatively.

I can mention the kinds of uncertainties that we have had in the National Academy of Sciences committees, where we assess the effects of various chemicals on ozone and that sort of thing. We think that our knowledge of the chemistry of the stratosphere is in pretty good shape. However, we have had over the years a number of surprises, and we have changed our estimates of the amount of ozone destruction several times within about a 10-year period, based on newly acquired information.

In some sense, the question you have asked relates to that and it is hard to know whether, if we convened a learned body to consider these things, that we would come up with something new and qualitatively different, or whether we would just make minor quantitative changes.

Now, that is mainly in the area of atmospheric chemical changes. If we talk about climate, that is a whole different kind of

game. There is a large national climate program with many components, extremely complex, and a lot of people are working on climate-related problems.

I mention in my statement that perhaps where we need some constructive thought is in knitting chemical effects into climate models. I think the basic thrust of climate research today focuses on physical effects, on how we simulate climate as it exists now and how we could use those simulations to forecast climate changes in the future based on the changes in the amount of solar radiation that comes in, how we simulate the effects of ice ages and that sort of thing. But chemical interactions in the atmosphere are not taken into account explicitly in these models, and I think that is where new and useful information could come.

Mr. OSTROV. Professor Birks, we would be interested in hearing your views on that question, and also those of Professor Westing.

Professor BIRKS. In the area where we have begun to do investigations, there is sort of no precedence for studying dispersal of particulate matter throughout the entire Northern Hemisphere. There were no good models available that treated photochemical smog in a global way, including transport, and treating the smog in the high degree of sophistication as far as the kinds of chemicals that you could put into that smog. We had to limit ourselves to the ethane, for example, that came from the natural gas wells as an example of the kind of calculation. So I think there are a lot of possible effects on the Earth's atmosphere, that there are models or potentials for developing models for that haven't been explored yet.

There are questions that have been thrown out but haven't been dealt with in any quantitative way at all. For example, what happens when you detonate weapons at very high altitudes, in which one is concerned then with the X-rays coming back into the Earth's atmosphere and producing oxides of nitrogen in the upper atmosphere. One can make sort of back-of-the-envelope calculations, but one really needs to look at these kinds of things in a more detailed way with more sophisticated models. So I think there are a lot of areas, where if there were funding available, and if you could get scientists interested in these problems and sort of overcome the stigma associated with working on nuclear war problems, I think quite a bit more could be learned.

It would be nice to have forest experts work on the problem, giving them a nuclear war scenario and telling them where the likely targets are, how much forest area would burn. I imagine that forestry experts could make a much better estimation of that than Paul Crutzen and I were able to make. Given their estimates, one could then use another kind of model to calculate more accurately where the sun-blocking would occur, whether throughout the entire United States, and how severe it would be. So I think yes, if we had some funding sources, then one could do a much better job on calculating these atmospheric effects.

Mr. OSTROV. One of the intriguing things that we deduce from your testimony and that of Professor Friend is that a lot of the effects that you hypothesize could happen in sequence. There could be Sun blockage as a result of particulate matter from fires, followed by photochemical smog, followed by a long-term ozone depletion. It is not clear to me that the public in general, or the deci-

sionmakers who are in a position to assess those effects, are really aware of them and of the gravity of these things happening in sequence.

So one of the things that would be of interest is whether a symposium made up of scientists in these disciplines who were in a position to assess all these things in the aggregate would provide a valuable data base for utilization at the political level by decision-makers in both the United States, the Soviet Union, and the other superpowers.

I just note as a footnote in your case, Dr. Friend, that a lot of the information that has come up since 1975 and that has enabled you and Dr. Chang at Livermore to hypothesize the effects that you now believe to be the case is the product of very recent research. To my knowledge, this is perhaps one of the first public forums in which that information has been communicated.

Professor FRIEND. Yes, I daresay that's true. Some of the chemical information has just been published in the National Academy report on ozone reduction.

I will say I was also a member of the two committees, one on biological effects, one on chemistry and physics, relating to the ozone reduction. I was also involved with the initial assessments which were begun because of the SST problem, the effects of the SST on the atmosphere. The scientists studying biological effects were asking for studies to be funded, for information to provide basic information in 1973. The same exact studies are being asked for now in 1982. A little money was put forth to do some studies on radiation effects in the environment, and then a lot of that was taken back.

There has been very little accumulation of knowledge in the detailed effects, the mechanisms of how ultraviolet-induced damages are caused, what is the action spectrum, the very basic phenomena on a molecular level. Our knowledge needs to improve on those things and also on the effects on particular types of vegetation. The biologists have been calling for financial support steadily all along and have really gotten none.

Professor WESTING. Professor Friend really suggested what I was going to suggest with respect to the need for funds. We really don't know an awful lot about the effect of enhanced ultraviolet radiation on crop plants or on oceanic plants. For example, we do not really know whether, even if two-thirds of the plankton are destroyed by enhanced UV flux, whether the one-third that is not destroyed will not simply fill the gap. There are some very important and fundamental questions that just have not been answered that deal with oceanic and terrestrial and agricultural ecosystems with respect to enhanced ultraviolet radiation. That can be done. It is amenable to research at the laboratory level, at the greenhouse level, and even at the field-plot level. Thus, I certainly would suggest that this is a very important thing to do.

You asked about an international conference at some high level. Having been involved with the International Physicians for the Prevention of Nuclear War, I realize—the sort of thing that Dr. Abrams was describing earlier—how important it is to have conferences of this sort just so that public awareness and the awareness of legislators and so on be enhanced.

The immediate medical effects of a nuclear attack are very straightforward and the type of material that is discussed at those conferences, and at that high level between Soviet and United States physicians, is nothing very profound from the fundamental, scientific standpoint. Yet from the standpoint of getting the message across, it is extremely important. So a conference would certainly be consciousness-raising at various levels.

The medical effects, even though known, have to be understood more widely. It certainly has to be stressed that the long-term environmental effects are just now becoming known within the scientific community; and the potential gravity of these and the large uncertainties involved and the real difficulties in modeling, the real difficulties in just establishing the models are also just becoming known. Then there are the real difficulties in deciding whether the attack will be primarily with 2-megaton bombs or primarily with 100-kiloton bombs or at high altitudes or low altitudes. You know, a 5,000-megaton war could kill everybody on Earth if every one of the bombs was a slightly underground explosion, set for surface with slight penetration, thereby creating vast amounts of fallout.

That one big Bravo test at Bikini in March 1954 would have killed everybody in the State of Massachusetts, or an area of that size, because it was a ground burst. A high altitude burst would do other horrible things.

Somebody mentioned earlier that small explosions would not have so much of an impact on the stratosphere, but even there we do not know for sure. In fact, lately people have been talking about what is referred to as the tunneling effect. If two or three small explosions are fairly close to each other in space and time there will be a tunnel that develops up into the stratosphere. There might actually be more of an adverse impact on the stratosphere from several small explosions if they are near each other in space and time than from one large one of the same explosive force. So these uncertainties as to the location of the bombs, the size of the bombs, whether they are high or low in the atmosphere or at the surface, all of these factors provide such an enormous amount of uncertainty that the most we can do in this regard is really discuss overall parameters and point out that the effects are extraordinarily unpredictable and perhaps life-threatening over vast areas.

Mr. OSTROV. One of the really puzzling things about this is that seemingly the information that has been developed, particularly in the health area, is being disseminated in the Soviet Union as well as the United States. In telephone discussions with Dr. Bernard Bell at MIT, he advises me that many of these scientific effects are well known within the upper ranks of the scientific world of the Soviet Union. And yet, within the Soviet Union, civil defense proceeds apace, and certainly in this country civil defense is considered at high official levels.

The really puzzling thing is, how do we effectively communicate what the scientific world is saying about the medical, atmospheric, and general scientific effects of nuclear war to decisionmakers in all of the superpowers?

Would an international forum tend to crystalize these questions in a way that would be more comprehensible to some of the deci-

sionmakers, or is there some other mechanism that might be effective?

Professor WESTING. I can answer that very quickly and briefly. I think a session of the sort that you suggest would be extraordinarily important, because, in fact, the right hand does not know what the left hand is doing. Dr. Abrams discussed this penetration of information into the Soviet Union at one level, which is defined by the Soviet Academy of Sciences and of various similar academies of medicine and technology, and the word is getting out. Then the Soviet military planners go their merry way. I have a feeling that what is happening in Washington is very similar. The Defense Department is going its way and doing what it thinks is right, and then some other branch of government is doing something rather very different. Some of the things the Pentagon is doing with respect to civil defense, as you mentioned, are just downright silly.

So I think, to get back to what you said, I think conferences of the sort you suggest are very important, so that more and more people recognize what the situation really is.

Mr. OSTROV. Professor Friend, do you have a response to that?

Professor FRIEND. I would just endorse what was said, that we need to have information and awareness percolating into the upper reaches of the administration, the people who make decisions on these things. Their awareness should be heightened.

I have the feeling, also, that they tend to go their way, listening to the advice they want to hear, and ignoring the rest of it, until the voices become so loud that they can't ignore it.

Mr. OSTROV. Professor Birks, I have a question with respect to your testimony. I want to make sure we understand what you said, that our understanding is accurate.

Is it correct that you said Sun blockage could be as great as 99 percent as a result of particulate matter from fires for a period of several weeks, perhaps longer, after a nuclear war?

If that is correct, it strikes me that it would be very difficult for humans to operate under those conditions, but it would be impossible, or nearly impossible, for animal life to operate under those conditions. And since we are all part of one large ecosystem, if the animals falter, do we falter, too? I want to make sure that our understanding is correct.

Also, what would life be like, as you see it, during that period when there might be Sun blockage as great as a factor of 150, I think you said?

Professor BIRKS. That's correct. The figures show that one could easily block in an average, averaged over the entire Northern Hemisphere, up to 99 percent or even greater amount of the sunlight.

As far as what the consequences of that would be, I haven't thought a great deal about what animals would be doing if the Sun didn't come up the next morning. I am sure they would be quite confused and it would upset their natural tendency to find food and do the sorts of things they are conditioned to do.

I think it would also be very important to people—I mentioned the psychological stress, that people are going to be very dazed following a nuclear war, in which they see people killed. They see members of their own family killed. They themselves perhaps are

injured. Then to add to that the fact that the next morning the Sun doesn't come up and it doesn't come up for days on end, I think the numbers of suicides that would occur would be enormous. We could probably never estimate that.

Then, as we pointed out in our paper, probably the most long term and important effect would be the effect on plants, which require sunlight in order to live, and plants, of course, begin the food chain for all of us. Without sunlight, at least most agricultural crops would die and certainly a great deal of other plants would die, so there would be those effects as well.

Mr. VOLKMER. I have to run and go vote. I will be back in about 7 minutes.

[Whereupon, the subcommittee was in recess.]

Mr. VOLKMER. Thank you for waiting. It took a little longer than I thought, but we can now continue.

I would like to get something a little clearer in my mind.

Let's assume that we have, say, a war in the 13,000-megaton range that a lot of the bombs are detonated near the surface of the Earth and hit many municipal areas, much of the refineries, oil wells, et cetera. We'll have fires for a period of time and a lot of particulate in the air. We will have a lot of dust, plus smoke, eventually possibly smog, correct?

Professor BIRKS. That's right.

Mr. VOLKMER. Now, that, so far, would only be in the areas where the blasts occurred; right?

Professor BIRKS. No.

Mr. VOLKMER. Plus drift?

Professor BIRKS. As far as the smoke is concerned, because of the 5- to 10-day residence time of the smoke, it is going to be spread pretty much around the whole Northern Hemisphere.

Mr. VOLKMER. All right, let's say the Northern Hemisphere, but not the Southern Hemisphere.

Professor BIRKS. The Southern Hemisphere probably would not be impacted by the smoke.

Mr. VOLKMER. Now, let's say in the Northwest, which is where much of our forests are, that we have very little warfare—maybe the Seattle area and that's about all; let's say they didn't attack Montana and Wyoming and Idaho and those areas. Would you still have fires in those other areas?

Professor BIRKS. You're going to have fires only in the vicinity of where nuclear explosions take place.

Mr. VOLKMER. OK. Now, this particulate directly from the blast and not necessarily from the fire is going to be highly radioactive; is it not?

Professor BIRKS. Well, the particulate matter from blasts that occur in the surface of the Earth, the ones caused by dust thrown up, that would be radioactive; yes. Particulate matter produced by forest fires would not be radioactive.

Mr. VOLKMER. I realize that.

But that radioactive dust is going to go up and eventually come down, is it not, or will it stay there?

Professor BIRKS. No; it's going to come back down.

Mr. VOLKMER. Once it comes back down, it is going to affect the food supply, is it not, even if the food supply doesn't die and wither

away because of lack of sunlight? It is still going to be affected by radioactive particulate?

Professor BIRKS. Well, I am not an expert in the area of radioactive contamination, but it is a problem of contaminating the food supply more than killing the crops.

Mr. VOLKMER. Yes; and there would be contamination of the water, also.

Professor BIRKS. Right.

Mr. VOLKMER. Now, the only effect that all of this would have on the Southern Hemisphere is basically the effect on the ozone layer; is that correct?

Professor FRIEND. Not quite, because the radioactivity that gets injected into the stratosphere will be carried around the world; particularly the long-lived material will get into the Southern Hemisphere and deposited on the surface there.

Mr. VOLKMER. Eventually it would be deposited?

Professor FRIEND. Yes.

Mr. VOLKMER. It depends on the amount of the deposit as to the effects that it has?

Professor FRIEND. Their levels of deposition will be lower than those in the Northern Hemisphere by quite a bit, but there will be enhanced radiation in the Southern Hemisphere from that.

Professor WESTING. Roughly speaking, one could say that if the war were limited to the Northern Hemisphere, 70 percent of these effects would be limited to the Northern Hemisphere, but 30 percent would sneak over into the Southern Hemisphere. The major part of those tropospheric effects would remain in the Northern Hemisphere. The ozone effect, being largely a stratospheric problem, would spread around and pretty well equalize throughout the entire world.

Now, with respect to the radioactive fallout, the major problem there is what falls out in the early days and weeks after the explosions, and therefore would be relatively close to where the explosions occurred. Then the radioactive debris that gets up high takes quite a while to fall out again and gets distributed around the world, including both hemispheres. This would add radioactive body burdens throughout the world that would be bothersome, but that would not have that enormous spectacular impact that you have immediately following a nuclear war.

That long-term fallout would be the sort of thing you pick up statistically. For example, there used to be a certain leukemia rate, that leukemia rate might be doubled or trebled. But that would spread out over many decades. That is, of course, a terrible medical catastrophe, but it is not a catastrophe in the same sense that the immediate fallout effects are.

Mr. VOLKMER. Mr. Clement.

Mr. CLEMENT. Thank you, Mr. Chairman.

Professor Friend and Professor Birks, I have some problem reconciling your two papers, simply because I don't understand your models I think as much as anything else. Professor Birks, you came up with a scenario in which you came to a total of some 5,700 megatons. Professor Friend, your scenario uses some 13,400 megatons, which is more than double.

How do you reconcile your two different scenarios with a probable nuclear holocaust?

Professor FRIEND. How would I compare them?

Mr. CLEMENT. Yes.

Professor FRIEND. Well, when I looked at those, the only thing that occurred to me that might be different from what Chang said—he took the OTA total arsenals and said: “Well, we’ll blow them all up.” It occurred to me that in a real nuclear war there might not be a chance to blow them all up, but they might get a large fraction of it up. So 10,000 megatons wouldn’t be out of the realm of possibility in my view, although I am no expert in how these things are dispatched.

I am sure that the timing can be quite exquisite in these things and that if you miss a few seconds you miss being able to fire off the last 20 percent or 30 percent or whatever.

Mr. CLEMENT. How do you view that response, Dr. Birks?

Professor BIRKS. Well, we actually evaluated two scenarios as far as the ozone depletion is concerned. The first of these scenarios, which is our main scenario, the one that we did most of our work on, was as you said, 5,700 megatons. This scenario was developed by a group of people not to be the most probable scenario, because no one can say what the most probable scenario is, but to be sort of a medium scenario, one that is not very small but one that doesn’t blow up every weapon. So it is a very plausible scenario.

Another aspect of this particular scenario was that the weapons that were chosen for the scenario were all fairly small weapons, taking the smaller distribution of weapons from the available arsenals. So all I can say is that this is one possible scenario. One has to choose a scenario to evaluate the environmental effects, and it turns out the ozone depletion problem is fairly sensitive to what scenario you pick. Other effects may not be quite as sensitive to the actual scenario.

Mr. CLEMENT. Did either of you include in your calculations the additional burden of radioactivity that will undoubtedly result from the destruction of nuclear powerplants and industrialized areas, or the destruction of nuclear propulsion units on naval vessels?

Professor FRIEND. That was not included in my evaluation of the updated effects. In the National Academy report in 1975 these things were mentioned but not evaluated directly. It was felt they would be localized effects. You would not have an enhanced nuclear explosion but you would spread radioactivity around in the region where the blast occurred. Again, that was not considered to be important for long-term global scale effects. But for local effects it certainly could be terrific, both for short-term acute effects and long-term contamination of the region near the blast. These effects could add considerably and we did not evaluate it.

Mr. CLEMENT. Did either of you—

Professor WESTING. Could I slip in one point there?

Mr. CLEMENT. Certainly.

Professor WESTING. There have been some estimates made in that regard. Essentially, what it does, if you attacked an area with, let us say, a single 1 megaton ground burst, that would make a certain area of land, several tens of thousands of acres of land, unin-

habitable because of the radioactive contamination for some lengthy period of time. You could not farm it, you could not live in it and so on.

If the attack included hitting a nuclear-powered electrical generating station, that would be the equivalent of having used a bomb 3 to 10 times the size used in terms of the area made uninhabitable. Thus, if you hit a nuclear-powered electrical generating station with a 1-megaton bomb, that would be the same as having hit another area with a 3- to 10-megaton bomb in terms of the size that is made unusable for habitation.

Mr. CLEMENT. Considering the number of naval vessels that are now nuclear powered, and the expectation that surface bursts would probably be used against them, it becomes a rather large contribution to a potential total; does it not?

Professor WESTING. There are several hundred submarines in the world that are nuclear powered, and it depends upon whether they are destroyed and the radioactive debris in them is dissipated in the open ocean, or whether they are in a harbor or near land at the time of destruction. If they are out in the open ocean, the radioactive burden on the ocean would be increased somewhat, but there would not be any spectacularly obvious effect.

Mr. CLEMENT. Unless, of course, they were caught near the surface and a surface burst managed to vaporize the vessel and the nuclear components there inside.

Professor WESTING. Yes. And since submarines are also often in port and could be destroyed while they are there, that could enhance the damaging effect of any attack on that port.

Mr. CLEMENT. Let me ask a final question, if I might.

Did either of the scenarios you worked with take into consideration the possibility that powers other than the United States and the Soviet Union would enter into a nuclear exchange?

Professor FRIEND. We did not consider that. The effects that we evaluated are essentially proportional or stem directly from the release of energy. So it is 10,000 megatons or 13,000 megatons in the two evaluations that we did. I didn't consider that anyone else would add appreciably to that yield in our scenario.

Again, this scenario was not meant to be real, but just realistic. I think there's a difference.

Mr. CLEMENT. Professor Birks?

Professor BIRKS. If you look at the nuclear stockpiles of the other three nuclear nations, they are only a very small fraction in terms of total megatonnage. So as far as our scenario was concerned, we don't have to write names of countries on the individual explosions. But the targets that were assigned were assigned to most countries in the Western World as we know it, the allies of the United States and the allies of the Soviet Union.

Mr. CLEMENT. You know, it is kind of ironic to sit here discussing this, particularly in this room, where you look around and you realize that we have got this tremendous technology that leaves us poised for the great voyages of exploration to the other planets and other galaxies, and at the same time we have got the ability to totally destroy everything—in seconds in the great cosmic time frame.

Walt Kelly had a great philosopher named "Pogo," who once said, "We have met the enemy, and he is us."

Thank you, Mr. Chairman.

Mr. VOLKMER. I have a few more questions.

Dr. Birks, would you tell us more about how the amount of ozone depletions affects ultraviolet enhancement?

Professor BIRKS. Well, we did some calculations with our model—this is our 10,000-megaton model—to determine how much the effective dose of ultraviolet radiation would be enhanced. We based this on what is called an action spectrum, which is the action spectrum for Sun-induced reddening of skin, the erythema spectrum.

I guess the important thing to realize is that this is not a linear function. A reduction of 50 percent in the ozone shield does not cause simply a 50-percent increase in ultraviolet radiation, but rather at midlatitudes it will cause something like a 4.5 increase in the amount of effective UV damaging radiation. This is also a function of latitude, and at midlatitudes I believe it is about a factor of 4.5 for a 50-percent reduction.

Mr. VOLKMER. And if you get more into the northern or southern latitudes it would be less?

Professor BIRKS. Well, the farther you go north, the greater is the enhancement. There is less UV radiation coming through the northern latitudes—

Mr. VOLKMER. That's what I mean. As far as enhancement is concerned, it would be reduced.

Professor BIRKS. No; the enhancement is actually greater.

Mr. VOLKMER. As you go north?

Professor BIRKS. The relative amount of UV radiation coming through after ozone depletion is greater in northern latitudes. If you take how much there is after the war and divide it by how much there was before the war, that enhancement factor is greater than if you do it at the Equator.

Mr. VOLKMER. There has been testimony and discussion here about ozone depletion from a nuclear blast and increasing ultraviolet rays. We have also had the testimony from Dr. Birks with respect to sun blockage of up to 99 percent.

Would those two phenomena in any way cancel each other out?

Professor BIRKS. What one has to look at is the time scale for these phenomena. The shortest time scale is associated with the smoke production. As long as fires are burning and producing smoke, then we have the blockage of sunlight. So this first phenomenon will only occur as long as fires burn, which would only be a few weeks probably. So as long as the fires burn, there will be a blockage of sunlight.

Mr. VOLKMER. Will that block the ultraviolet?

Professor BIRKS. Yes.

Following the removal of the particulate matter from the atmosphere, then we have the possibility of the photochemical smog formation that I talked about. Actually, the ozone is produced by the photochemical smog which will itself filter some of the ultraviolet radiation from the sun. But the photochemical smog time scale is on the order of a few months, so it would persist for a few months following the removal of the particulate matter from the atmosphere. This is finally terminated because the oxides of nitrogen and

the hydrocarbons undergoing chemical reactions form various species which are removed from the atmosphere, both by dry deposition and also be rain.

But then, remember that the time scale for the depletion of the ozone layer is on the order of a few months. Our model showed a maximum ozone depletion occurring at about 3 months time. So at about the same time the photochemical smog begins to fade away, then the ozone layer starts to be depleted and then significant amounts of extra UV-B radiation.

Mr. VOLKMER. What would be the effect on the stratospheric, ozone layer if we had nuclear blasts, say, in the high altitudes? Let's say the Soviets fired on our satellites using nuclear warheads to knock them down.

Professor FRIEND. That's a very important question. If a nuclear weapon is detonated in space, then it can have a much greater effect on the atmosphere on producing nitric oxide in the upper atmosphere in the stratosphere. Consequently, it has a much greater effect on ozone reduction, which since it happens at high elevation would also last a longer time. So on a megaton for megaton basis—

Mr. VOLKMER. The effect would be a lot greater?

Professor FRIEND [continuing]. The effect would be a lot bigger for depletion of ozone, the detonation in space. So if, somehow, there were a significant number of weapons exploded in space, then that could be a major real disaster in both hemispheres from ozone destruction.

Mr. VOLKMER. Do you have any additional questions?

Mr. OSTROV. I have several questions.

Professor Friend—and Professor Birks may respond—in the Ambio magazine scenario used by Professor Birks in his calculations, only 776 weapons exceeding 1 megaton yield were used, and the total weaponry launched equaled 5,692 megatons. Under these conditions, Professor Birks concluded there would not be significant ozone depletion.

Do you agree with that?

Professor FRIEND. We're not in total agreement in the sense there is kind of a technicality. I think Professor Birks referred to the amount of ozone destruction is quite sensitive to the yield of the individual weapons used because of the height of the cloud that results from the burst. Those are not easily scaled just by multiplying. I think we have somewhat of a disagreement in our calculations as to how much of the cloud from a 100-kiloton burst would get into the stratosphere.

Mr. OSTROV. So you believe there might be some ozone depletion even were lower yield weapons used of the variety postulated in the Ambio scenario?

Professor FRIEND. There would be some. The way Dr. Chang approached this problem, if you will, was to say: "Let's try all the U.S. weapons with yields less than half-a-magaton," and that came out to be only 5 percent of the ozone. So I don't think we are awfully far off.

In the way we have handled the problem, I think perhaps the major difference is in the constitution of the larger yield, how

many weapons of larger yield are going to be used. Those are very important.

Mr. OSTROV. That's a very significant point.

Do you want to respond to that, Professor Birks, or do you think it has been adequately addressed?

Professor BIRKS. Well, I think probably, if Dr. Chang used exactly the same scenario with exactly the same distribution of weapon yields, that he would calculate the same nonchange in ozone reduction that we calculate. We used the same altitude distribution with the bomb clouds that are produced as a function of yield that were used in the 1975 National Academy of Sciences report, and I assume that Dr. Chang is using that same distribution.

The model contains essentially identical chemistry in it, and the means of solving those equations for the time dependence of the chemistry I think are very close. So I would be very surprised if Dr. Chang's model didn't produce our results if he used exactly our scenario. Although it is possible there would be some difference in the way the two models treat the transport, or in the way the models treat the chemistry, that would provide some difference.

One of the aspects of our model which has been shown by many other models of the stratosphere is that oxides of nitrogen injected into the lower stratosphere actually cause ozone to increase. This is the result of certain chemical reactions that take place in the lower stratosphere. So this partially offsets any ozone depletion that occurs above these lower altitudes of the stratosphere. So I think it is basically a technical problem. It is the reason we tested our model with a larger scenario. The 10,000-megaton scenario with the larger yield weapons did show greater than 50 percent ozone depletion. I don't think there's a major difference.

Mr. OSTROV. As you recede from 10,000 megatons to a lower level, the adverse effects are not linear. Would it also be correct that as you increase from 5,000 megatons up toward 10,000 megatons that the adverse effects are also not linear in that direction, that they begin to increase more than with just straight linearity?

Professor BIRKS. Of course, that's true. The nonlinearity applies in either direction. But I think actually the nonlinearity works in the other way, that if you're at high yields and then you back off on the yield a bit, it doesn't substantially reduce the amount of ozone depletion that you calculate, because you sort of saturate the system with oxides of nitrogen in higher concentrations.

Professor FRIEND. I agree with that, that it is a saturation effect. So if you decide that you're going to try calculation with half the yield, you will get more than—you will still have a depletion of ozone which is bigger than half of what you originally calculated.

Mr. OSTROV. The critical levels begin to occur as you start proceeding from 5,000 megatons up toward 6,000 and 7,000 and 8,000?

Professor FRIEND. Saturation effects begin to set in fairly early, I think, and it curves off somewhat gradually. So it is nonlinear over a very large range.

Mr. VOLKMER. If I may interject 1 minute, does the amount of megatons per bomb affect the linearity?

Professor FRIEND. Yes.

Mr. VOLKMER. In other words, assuming 10,000 megatons, the deployment of 100 megaton bombs, wouldn't have the effect of using all 1,000-megaton bombs; is that correct?

Professor FRIEND. Yes, that's correct, particularly due to the fact, as Professor Birks mentioned, that in the lowest elevations, to the best of our knowledge, oxides of nitrogen can actually increase the amount of ozone.

Mr. VOLKMER. Which you wouldn't have in the 1,000 megaton.

Mr. Gore?

Mr. GORE. Thank you very much, Mr. Chairman.

I want to apologize to this panel and the one proceeding them for the fact that I had these amendments pending on the floor that had to be voted on. It is just unfortunate, but this is one of those days. We hope that this is going to be a very useful record.

Let me just ask one brief question. Professor Birks, you have done work on the possibility of forest fires. Is that dependent on the proximity of forests to the blast—it seems like it would be—and is there any analysis that has been done of that?

Professor BIRKS. Of course, you're right. The amount of forests that burn is simply very closely related to the number of fires you start, which has to do with how close the thousands of targets—in our scenario, something like 17,000 targets—are to forests.

However, in those calculations we think we have underestimated the amount of forest fires that would result, and certainly in comparison to what the U.S. Forestry Service estimated would be the range of forest area burned was below their minimum estimate. Their maximum estimate is six times greater than what we estimate, and that is for the United States alone.

One thing I have looked into is simply thinking about this in terms of the thermal radiation produced by the nuclear weapons. If you explode 5,000 megatons of nuclear bombs—and you can divide this up into 5,000 1-megaton bombs or 50,000 100-kiloton bombs; it doesn't make a real big difference in the calculation—it turns out that the area that is exposed to 40 calories per square centimeter is something like 250,000 square miles to over 400,000 square miles. Our estimate for forests burning is 360,000 square miles. Forty calories per square centimeter is enough to char human bodies, and most trees would just be charred, but any dry leaves or small branches and so forth burst into flames at that level of radiation.

So, for that reason alone, I think that this is an underestimate, plus the fact that we have not included fires in cities. We only did this as sort of an example calculation and we chose forest fires because there are good data on what quantities of smoke are produced by forest fires. But the cities targeted by these nuclear weapons would contain probably more biomass than the forests that we consider to be burned in our scenario.

Mr. GORE. Thank you very much. We may have some supplemental questions for you to answer.

Mr. VOLKMER. I want to thank the panel.

We will now hear from Dr. Frank Von Hippel from the Center for Energy and Environmental Studies.

Mr. GORE [presiding]. Dr. Von Hippel, we are honored to have you join us here today from Princeton. I might note that you are also the elected chairman of the Federation of American Scientists

this year. You are extremely well known for your work in this field and related fields. We feel very privileged that you are with us to close out today's hearing.

Without objection, your prepared remarks will be put in the record in full, and we invite you to proceed.

STATEMENT OF FRANK VON HIPPEL, SENIOR RESEARCH PHYSICIST, CENTER FOR ENERGY AND ENVIRONMENTAL STUDIES, PRINCETON UNIVERSITY

Dr. VON HIPPEL. Thank you very much, Mr. Chairman.

I think it is a very remarkable hearing that you have put together. It is an important step toward developing further understanding of this problem. Although I haven't been able to attend all of it, I have read all of the statements and I have learned several things that I didn't know before—and I have read quite a bit in this area before.

Since the staff raised this question with me over the phone and also Mr. Clement asked the question of the previous panel, I thought I just might add to the answer that was given about what would happen if you target nuclear powerplants, and how this would make things worse. I have never done the calculations before, but since I have worked in the area of reactor safety, as well as weapons effects, it wasn't very difficult to do.

The inventory of long-lived fission products in one large power reactor is equivalent to that which would be produced by the explosion of about 40 megatons of bombs. For short-lived fission products, the inventory of a reactor corresponds to a much smaller megatonnage so I think it is appropriate to focus on the long-term contamination problem rather than on the short-term fallout issue.

There are the equivalent of about 150 large reactors in the world today. That would be the equivalent of about 6,000 extra megatons that one would add to the long-term radioactive contamination problem that you have been hearing about. If one was releasing from fission in nuclear powerplants the equivalent of the world's total energy consumption today, that would be equivalent of about 4,000 large nuclear powerplants and the number would go up to about 150,000 megatons equivalent. Consequently, although today the bombing of nuclear powerplants would not make an all-out nuclear war that much worse, potentially in the future it might be a major amplifying factor. That is something that had never really registered on me before Mr. Clement asked his question and I did the arithmetic.

Shall I proceed with my prepared statement?

Mr. GORE. That would be fine. If you care to summarize any portion of it, that's okay, too. But it's up to you.

Dr. VON HIPPEL. I will summarize it.

The basic point is that very little effort has gone into the understanding of what would happen if these weapons were actually used. I had as an example of how unexplored this territory, still is, I need only point at the work of Professors Birks and Crutzen who discovered a major effect that nobody had thought of before. This work was done as a result of the small Swedish magazine, *Ambio*, asking them to write an article.

I called up the editor of *Ambio* and asked her "How much money did you spend on this issue?", I wanted to get an idea of the cost of achieving such large increments in our understanding. She answered "\$35,000." That is a pretty small amount compared to the tens of billions of dollars that we and the Soviets are spending each year on developing improved abilities to use these weapons.

I must say that I am frightened about how little effort has gone into trying to understand these questions in our Government, at the same time that very elaborate scenarios for fighting a nuclear war are developed. I mention in my prepared testimony the experience that we all had in 1974 when we learned that the Defense Department, which was talking a great deal about the possibility of limited nuclear war, hadn't looked to see what the consequences would be for people. We had very elaborate calculations of what would happen to the weapons being targeted, but, when Secretary Schlesinger was asked "How many civilian casualties are you talking about in a limited nuclear war?", he said maybe "15,000, 20,000, 25,000 deaths." After he had been asked for a briefing and to come back with some documentation of his numbers, he increased the number to 800,000. Then, after the assumptions that had been used in his calculations had been reviewed by an expert panel under Jerome Wiesner, then the president of MIT, the numbers rose to 2-20 million. This history shows how out of touch with reality these discussions were.

Of course, these numbers that were quoted still didn't take into account the kinds of effects that you have been hearing about today—the epidemics, ozone effects and so on. They were just straight blast and fallout radiation effects.

As you know—I know it has been discussed earlier in the hearing—the situation has not improved very much today. Apparently the leading expert on the effects of nuclear weapons in this current administration is T. K. Jones, who has said some remarkable things, such as "Everybody is going to make it if there are enough shovels to go around * * * Dig a hole, cover it with a couple of doors, and then throw 3 feet of dirt on top. It's the dirt that does it." Well, I think, after hearing the testimony today, you realize that that's a little oversimplified.

But it's not just T. K. Jones. I call him the administration's leading expert on this matter because people in the administration listen to him. Paul Nitze attached a calculation at the end of his testimony against SALT II in 1979 whose author was not indicated but was probably T. K. Jones—it was one of his type of calculations. The calculation purported to show that we wouldn't have a deterrent after the Soviet Union made a first strike on us. This calculation, which I think deserves more public attention, went like this: Prior to the Soviet first strike, they would have evacuated 80 percent of their urban population and they would have distributed the evacuees uniformly over a million square miles. All of these people would have been equipped with 2 week's supply of water and food and other survival equipment, and shovels, of course, and the knowledge and time to build shelters which would reduce their radiation dose from fallout to a half a percent of that they would otherwise receive on the surface.

After a Soviet first strike, the United States would have only 4,000 warheads left. Our 4,000 nuclear weapons would only cover 20 to 30 thousand square miles in the Soviet Union with 200 times the lethal dose, so we would only be able to kill 2 to 3 percent of the evacuees. Therefore, after 2 weeks they would come out of these shelters and take over the world. Of course, they would have no industry, no agriculture and no transportation—but they would somehow take over the world anyway. How exactly isn't explained.

That is Paul Nitze, who is supposedly a sophisticated specialist in the arms race and who has been in this business ever since he was involved with looking at what happened to Hiroshima and Nagasaki.

There seems to be almost a deliberate blindness to what we are talking about when we're talking about nuclear war. I have often noted in reading the military literature the use of language in such a way as to gloss over the human consequences. Consider, for example, the use of words which end in "cide", as in homicide, matricide and so on. I only found one use of such words in the literature, namely "fratricide", the destruction of one nuclear weapon by another. The destruction of people is termed "collateral damage" in the literature. That is another indication, I think, that nuclear war is a terrible subject and, if you're in the nuclear weapons business, you try not to think about its potential consequences. If you try not to think about them and succeed, however, then it is very dangerous for all of us. That's the situation we're in.

In my testimony I mention how we have learned accidentally about most of the effects of nuclear weapons. We learned about blast and heat effects at Hiroshima and Nagasaki, but we only learned accidentally about the fallout effects much later as a result of fallout landing on the Japanese fishing vessel, the Lucky Dragon, after a 1954 test. That was the first time the people realized how large an area could be affected by the fallout from one nuclear weapon.

Then, as a result of the controversy that Secretary Schlesinger touched off, we learned that the overlapping fallout patterns from an attack with 300 nuclear warheads on one of our Minuteman bases could be lethal for more than one thousand miles downwind. I don't think that was understood by many people before the controversy that Secretary Schlesinger touched off.

Then, of course, the effects of large nuclear explosions on the ozone layer were only accidentally discovered by people arguing about what the effects would be from a fleet of supersonic transports flying around up there.

I think it was the physicians' movement that got Dr. Abrams interested in this issue, and I think it is only due to his work that we understand what kinds of epidemics would occur after a nuclear war. I find his work mind-boggling. It makes the aftermath of a nuclear war real.

I attached to my testimony a letter that I wrote to T. K. Jones, after I saw a quotation from him in the Los Angeles Times, to the effect that, with the proper civil defense, it would take only 2 to 4 years for the United States to fully recover from an all-out nuclear war with the Soviet Union. I asked if he could provide me with the analyses on which he based his statement because I would like to

get a group—for example, sponsored by the American Physical Society—to really review this analysis. I think peer review is essential for any technical report on which public policy is going to be made. Unfortunately, I haven't gotten an answer to my letter and I wonder whether this committee would be able to induce an answer so that one could really finally join the issue and really get the larger scientific community to look at the kinds of analyses that are behind these seemingly crazy statements.

Mr. GORE. Let me say at that point that we asked the Department of Defense and the Defense Nuclear Agency to testify at this hearing. They have legal responsibility for assessing these matters. They declined to testify.

I am sure that were we to press Mr. Jones for the basis of his statement, we would likely not find a well-documented, footnoted, scientific study. I doubt that that would surprise you, either; would it?

Dr. VON HIPPEL. No. But I think that people at high levels have to be disciplined by being challenged to produce an analysis. I have written an article about this called *The Emperor's New Clothes*. We need more small boys to point out when the emperor is running around naked. If these statements are allowed to go unchallenged, people assume there must be something behind them. We know better, having seen on closer inspection that quite often the emperor is naked. But I think the general public still thinks that "the Government has access to all these experts and, therefore, they must know what they're talking about."

This has been one of my campaigns over past years: to try to get the Congress in particular to become more aware of the need for peer review of these kinds of statements and studies. I think the payoff can be enormous when it happens—for example, with Secretary Schlesinger's estimate of 15,000 to 25,000 deaths from a limited nuclear war. There was an enormous payoff from that in terms of an increased understanding of what we're talking about in a limited nuclear war. I think that all the Office of Technology Assessment studies which have come since owe their direct heritage to that original issue and they have certainly been a basis for a lot of other publications, including, for example, the *New Yorker* series of Mr. Schell. The number 2 to 20 million deaths is now quoted everywhere for the consequences of a limited nuclear war. Once you see crazy statements made by a high level official, there is a real opportunity for getting together a group of experts and saying: "Well, this is what the administration thinks; let's check it out."

More generally, I hope the effect of this hearing is to get more resources focused on this issue and get more information developed and made available to the public on the global consequences of nuclear war at a time when there is so much public interest.

When your staff contacted me, I tried to think about what kinds of institutional venues it would be possible to do this in—especially international ones—and I think it would be especially interesting in the international context.

There are two possibilities in particular that occurred to me, and I am sure more could be developed. One is that there is a precedent for U.N. auspices. There is something called the U.N. Scientific Committee on the Sources Effects of Atomic Radiation. I believe

that committee was originally founded to look at the effects of atmospheric testing. It has pulled together a very impressive report about once every 5 years, in a thick volume on our understanding of the food chain among other things, the pathways followed by radionuclides from global fallout.

The other possibility that occurred to me was a joint study between the United States and Soviet Academies of Science, I am sure there are many other possibilities but these are obvious ones. Others would take more work, but I think could be brought about.

[The prepared statement of Dr. Von Hippel follows:]

Frank von Hippel
 Senior Research Physicist
 Center for Energy and Environmental Studies
 Princeton University
 Princeton, N.J. 08544

The U.S. and Soviet Union have spent hundreds of billions of dollars on nuclear weapons and their delivery systems during the past decade and are planning to spend hundreds of billions more during this decade. Yet the amount of effort which has gone into understanding what would happen if these weapons were actually used is miniscule. It is so small that the editors of the tiny Swedish environmental magazine, Ambio, with an expenditure of about \$35,000 were able to organize a project that broke important new ground in several areas.

The level of ignorance that currently exists has allowed our nuclear policy makers to live in a fantasy world which we outsiders only rarely glimpse.

My own first glimpse began in 1974 when Secretary of Defense Schlesinger in his Annual Posture statement argued that the U.S. should be better prepared with options for limited nuclear responses¹

to a limited attack on military targets
 that caused relatively few civilian casualties...

When Schlesinger was asked in a Senate Foreign Relations Subcommittee hearing by Senator Symington,²

just what do you mean in numbers by
 "relatively few civilian casualties"?

the Secretary responded²

I am talking here about casualties of 15,000, 20,000, 25,000...

Senator Case pursued the issue and asked for briefings³

on the consequences of the wide ranges of possible
 "anti-military" attacks against the U.S.

Schlesinger came back with an estimate that a Soviet attack on U.S. ICBM silos would result in 800,000 fatalities.³

When an expert review panel convened by the Office of Technology Assessment suggested changes in the DOD's optimistic assumptions about the nature of the Soviet attack and the ability of the population downwind to take shelter against fallout, the DOD calculated numbers of fatalities ranging up to 20 million.⁴ These fatalities would mostly be due to the enormous swaths of fallout which would be laid out downwind of the missile silo complexes if groundbursts were used. Figure 1 attached, based on a figure that was published in Scientific American in an article by Dr. Drell and myself,⁵ shows the huge areas which could be covered by such fallout. Figure 2 shows a more recent calculation of the fallout patterns which would result from the explosion of a much smaller number of weapons on military nuclear targets in the Germanies.⁶

It appears that the Defense Department was busy investing billions in improving our capability to wage limited nuclear wars with very little understanding of what it was talking about.

Unfortunately the situation appears to have improved very little if at all in the eight years since this episode. We now have an Administration whose leading expert on the effects of nuclear war has stated that⁷

everybody's going to make it if there are enough shovels to go around... Dig a hole, cover it with a couple of doors and then throw three feet of dirt on top. It's the dirt that does it.

Obviously, our nuclear strategists -- and probably their counterparts in the Soviet Union have a lot to learn about the consequences of nuclear war!

We've known since the beginning about the effects of blast and heat from a nuclear explosion. Hiroshima and Nagasaki taught us about them. Most of the rest of what we've learned about the consequences of nuclear war we've learned by accident, however, rather than as a result of deliberate investigations.

We learned about the effects on humans of the radioactive fallout from a single large nuclear explosion in 1954 after a Japanese fishing vessel, the incorrectly named "Lucky Dragon," was caught in the fallout almost 100 miles downwind from a test on Bikini.

We learned how the radioactive fallout from nuclear war would poison food and water supplies worldwide as a result of the debate over atmospheric testing during the late 1950's and early 1960's.

As a result of the controversy that Secretary Schlesinger touched off, we know that the overlapping effects of many fallout patterns can be lethal 1000 miles downwind.

As a result of the controversy about the proposed supersonic transport, we learned how seriously the earth's protective ozone layer could be damaged by the explosion of many nuclear weapons.⁸ We still know very little, however, about the potential impacts of the resulting greatly intensified ultraviolet radiation on the many vulnerable links in the delicate web of life which supports us.

As a result of the physicians movement we have learned about the terrible epidemics which might follow a nuclear war.⁹

And, as a result of an initiative by the editors of Ambio we have learned about the long darkness and burning smog which would also follow a nuclear war.¹⁰

We still have to hear from the social scientists about their thoughts as to whether the survivors of a nuclear war could put a modern society together again. We have only the assurance of the Administration's leading expert as reported in the Los Angeles Times:⁷

with the proper civil defense, it would take only two to four years for the United States to fully recover from an all-out nuclear war with the Soviet Union.

I wrote to Mr. Jones in February asking for descriptions and analyses of the civil defense arrangements to which he was referring (see figure 3).

I offered to arrange for a peer review of the analyses. Thus far, however, I have received no response.

Why are we so unwilling to invest some modest resources to learn about what would happen to us in a nuclear war when we are willing to debate endlessly the most far-fetched threats to our nuclear weapons?

Perhaps, this Subcommittee can help break this trance in which we are preparing for nuclear war while trying not to think about it. I hope that this fine hearing marks the beginning of such an effort. I would be pleased to join in and help in any way I can. If the governments of the superpowers can devise no better policies than the continued refinement of their weapons of mass destruction, they could at least tell the world in as accurate and comprehensive way as is possible exactly what would happen if history should repeat itself and an arms race once again leads to all-out war.

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2. U.S. - U.S.S.R. Strategic Policies, Hearing before the Subcommittee on Arms Control, International Law and Organization of the Senate Committee on Foreign Relations, March 4, 1974, p. 19.
3. Briefing on Counterforce Attacks, Hearing before the Subcommittee on Arms Control International Law and Organization of the Senate Committee on Foreign Relations, September 11, 1974, pp. 1, 13.
4. Analyses of Effects of Limited Nuclear Warfare, Committee Print, Subcommittee on Arms Control, International Organizations and Security Agreements of the Senate Committee on Foreign Relations, September 1975, p. 23.
5. Sidney D. Drell and Frank von Hippel, "Limited Nuclear War," Scientific American, November 1976, p. 27.
6. William Arkin, Frank von Hippel, and Barbara G. Levi, "The Consequences of a 'Limited' Nuclear War in East and West Germany," Ambio, June 1982, p. 163.
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9. Herbert L. Abrams, "Infection and Communicable Diseases" in The Final Epidemic, Physicians and Scientists on Nuclear War, Ruth Adams and Susan Cullen, eds. (University of Chicago Press, 1981), p. 192.
10. Paul J. Crutzen and John W. Birks, "The Atmosphere After a Nuclear War: Twilight at Noon," Ambio, June 1982, p. 114.

FIGURE 1

FALLOUT FROM AN ATTACK ON U.S. MISSILE SILOS

FATALITIES

-  GREATER THAN 50%, INDOORS ABOVE GROUND
 GREATER THAN 50%, OUTDOORS

ASSUMPTIONS

- 2-ONE MEGATON WARHEADS ON EACH SILO
- 50% FISSION YIELD
- SURFACE BURSTS
- TYPICAL MARCH WINDS

16-368 266

Preparing for Nuclear War While Trying Not to Think About It

FIGURE 2

FALLOUT PATTERN FROM
PREEMPTIVE NUCLEAR
ATTACKS WITH 200 KT.
GROUNDBURSTS ON 171
MILITARY TARGETS IN
THE GERMANIES

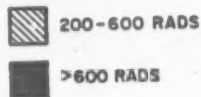
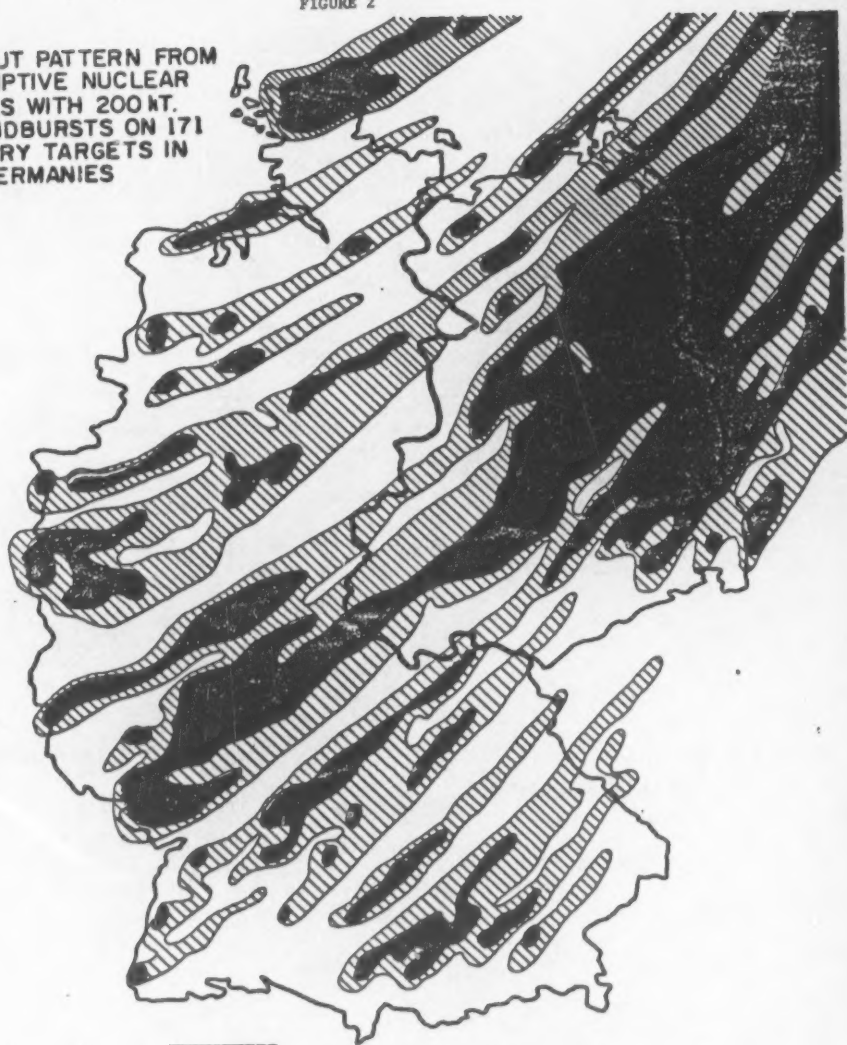


FIGURE 3

Princeton University

SCHOOL OF ENGINEERING/APPLIED SCIENCE
CENTER FOR ENERGY AND ENVIRONMENTAL STUDIES
THE ENGINEERING QUADRANGLE
PRINCETON, NEW JERSEY 08544

February 12, 1982

Mr. T.K. Jones
Deputy Undersecretary of Defense for
Strategic and Nuclear Forces
U.S. Department of Defense
The Pentagon
Washington, D.C. 20301

Dear Mr. Jones,

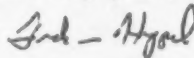
In the Los Angeles Times of January 16, 1982 you are quoted to the effect that

"with proper civil defense, it would take only
two to four years for the United States to
fully recover from an all-out nuclear war
with the Soviet Union."

Could you please send me a description of the civil defense arrangements to which you were referring and the analysis which shows that they could be so effective? I would like to arrange a review of those analyses. I am sure you will agree that it is critical that a national policy concerning our very survival be based on analyses that have undergone as thorough a review as is feasible.

Thank you in advance for your trouble.

Sincerely yours,



Frank von Hippel

FvH/zk

Mr. GORE. Thank you very much.

Mr. Volkmer.

Mr. VOLKMER. I have no questions.

Mr. GORE. You do agree, I take it, that the uncertainties are so vast in this area that it would be extremely useful to conduct further study and further work on this matter?

Dr. VON HIPPEL. Yes. I was involved in organizing this Ambio study, and I think, that the results are very impressive, considering the amounts of resources and the time involved. But there is much more work that could and should be done.

Mr. GORE. And that experience convinced you that some of these uncertainties might yield to further research?

Dr. VON HIPPEL. Yes. For example, I think that there are some new insights as a result of the work that Professors Westing and Abrams did to prepare for this hearing.

Mr. GORE. It occurs to me that there is a lot of international expertise to address these issues. I remember in grade school being quite impressed with an effort long ago—I guess it has been 25 years ago, when the International Geophysical Year was—I believe it was 25 years ago this year, 1957. I wonder if a second international geophysical year, focused on this matter might make any sense. Perhaps it could also address some other global environmental matters such as the CO₂ controversy that is also fraught with uncertainties, yet also looms over our future plans as a civilization?

What is your reaction to that idea?

Dr. VON HIPPEL. I think it's a wonderful idea. In fact, a study of the precedent of how that was pulled together would give one real insight as to how one could pull the expertise together that would be required for this kind of study.

Mr. GORE. And you think the Federation of American Scientists might help?

Dr. VON HIPPEL. We would be happy to help in any way we could. There is a much larger community, though, that would be—

Mr. GORE. Yes, I know. I just wanted you to put on your other hat for a second and take advantage of that as well.

It seems like an urgent task, and it seems clear that the state-of-the-art analysis at the present time is unclear and, to some extent, contradictory. Although, there is nothing unclear about the final conclusion as to the fact that the event that is euphemistically referred to as a "nuclear exchange" can never be allowed to take place.

It is possible that some of the uncertainties would, of necessity, remain. But I think it does make sense to try to answer these questions. The preparations for fighting a nuclear war are clearly going on rapidly, both in this country and in the Soviet Union, as if some of these further risks of long-term permanent global environmental damage did not exist. They are discounted now because the uncertainties are interpreted as insignificant concerns.

Dr. VON HIPPEL. I think that is, in fact, a very important point. The military, having concentrated on the purpose of these nuclear explosions, the destruction of some military targets or industrial targets, want to be conservative and, therefore, make sure that that destruction occurs and therefore assume that nothing will

happen that they don't understand and that isn't overwhelmingly guaranteed by the direct effects of the explosion. Of course, the other effects would mostly be on the civilian population and the social system and the environmental system that supports it, so they would be less relevant to the purpose of the attack.

I might mention one other thing. One question which seems to me to be critical and is perhaps more untouched than all the areas that have been discussed here so far in the hearing is a question that should be dealt with by economists and social scientists: "Could, in fact, society reconstitute itself after a major nuclear exchange?"

Mr. GORE. Mr. Volkmer.

Mr. VOLKMER. From what I understand here, I guess we could presume that the people of whole continents such as Australia, Africa or South America, probably don't have the slightest idea of what would happen to them?

Dr. VON HIPPEL. Well, what I was going to say—

Mr. VOLKMER. Because they are assuming that the attacks are going to be between Russia and the United States or the European nations; is that correct?

Dr. VON HIPPEL. I think that's right. These effects which haven't been explored, the one which you have been discussing today, really are global and would affect non-target countries.

However, in discussing the scenario that Ambio used, I became aware of the whole literature which relates to the balance of power in the postnuclear war era. For example, the Soviet Union, expecting to be a shambles, might be concerned that the Chinese would take over after an all-out nuclear war between the superpowers. A lot of bombs might therefore be directed toward China—just to make sure they weren't in good enough shape to take over afterward. Alternatively Brazil, if not targeted, might be the superpower of the postnuclear war era. A lot of countries that think a nuclear war would pass them by might, in fact, be targeted for direct effects in addition to indirect global effects.

This is a thought that hadn't occurred to me, and I was just horrified by it. Unfortunately there is so much concern about relative status after a nuclear war that there might be an effort to essentially smash everybody—not only the enemy.

I didn't finish a previous thought. I was wondering if it might be possible to have a hearing sometime asking economists and other social scientists to talk about how we would try to put together a viable society again after a nuclear war? I am aware of one study—I think it was a Rand study in 1963—which explored this question in a very preliminary way.

After a war there would be a race between the depletion of the surviving stocks of food and the reconstitution of the ability to grow more—to make fuel for farm machinery and so on. Above a certain level, of megatonnage which this the Rand report tried to estimate—the race would be lost by the surviving population. There would be a downward spiral of the society and it is not clear where that spiral would end. I am not aware of any effort by serious economists to look at that issue since.

Mr. VOLKMER. You have alluded to your communication with Mr. Jones regarding civil defense and other statements. Could you just

give us your personal views as to the feasibility of civil defense preparations, particularly in regard to radiation exposure?

Dr. VON HIPPEL. Well, I agree with Mr. Jones, that if, in fact, you have the supplies and have a shovel and can dig yourself in, and you know when the nuclear war is going to start, and you don't get sick and you don't freeze and you don't get bitten by a plague-carrying rat—then you might be able to make it for a couple of weeks.

Even if the country was successful in saving a large percentage of its population in this way, however, there is no way that you could save the support system for that population. The situation would, in fact, be worse than if most of the population had been killed and as a result the number of survivors were better matched to whatever support system existed after the war.

I think, therefore, that I agree with all your other witnesses who have been asked that question: Our civil defense system is really a bandaid for a cancer.

Mr. VOLKMER. We have discussed the possibility about having further advanced studies on an international basis. Is there any scientific forum that would provide an effective means for communications? Do you know of any existing?

Dr. VON HIPPEL. Going on internationally now?

Mr. VOLKMER. Yes, internationally, that would involve both this country and, say, the Soviet Union, plus other nations of the world.

Dr. VON HIPPEL. I am familiar with one continuing effort that has been done ever since the 1950's, the Pugwash group, which is basically a group of scientists, including representatives from both the Soviet Union and the United States who have been meeting annually since the 1950's. Such a group could be used as a channel for communications and questions between the two countries, but the resources of expertise that will be required here really is much greater than exists in any group like that.

If you were talking about the academies of sciences, then I think you have direct communications between them, although they may have been cut back to a considerable degree over the past few years in protest of, for example, the treatment of Sakharov in the Soviet Union.

Mr. VOLKMER. Of course, if their military looks upon any dissemination of information as detrimental, they wouldn't permit the dissemination of very much information anyway, would they?

Dr. VON HIPPEL. That came up in part of the hearing I was attending earlier on. I think Dr. Abrams was talking about a discussion on Soviet television by a group of Soviet and American MD's of the consequences of nuclear war. Didn't he say that on October 13 a tape of that program was going to be broadcast here? So the Soviets have been quite cooperative in this respect.

The point is often made that: "Well, we can discuss these things but the Soviets can't." It is true that when Soviet groups try to spontaneously demonstrate for an end to the arms race, as one group recently did, they end up in psychiatric hospitals. We know also what happened to Sakharov. But I think the debate that we have in the United States educates not only us but also the Soviet leadership. For example, before we had our debate 10 years ago over whether it makes sense to have antiballistic missile systems,

both we and the Soviet Union were deploying these systems. After our debate in the United States, I think the consensus developed here that such a system would cost less to penetrate than it would cost to build. The steam went out of our program as a result, and the leadership in the Soviet Union was also convinced. I think that it was only as a result of that debate that the political leaderships on both sides understood enough about what was going on to say "No!" to the people in the defense establishments who wanted to deploy these systems.

In the Soviet Union they don't have the ability to have a free discussion where people can come out and say critical things. So in a way we in the United States are carrying the responsibility for educating both sides.

Mr. VOLKMER. Thank you, Mr. Chairman.

Mr. GORE. Thank you very much. I enjoyed the questions.

Well, we will pursue this idea of an international effort. We may have a formal recommendation as a subcommittee. I don't know. We will have to discuss that. But certainly, as an individual member of the subcommittee, I think that it is an urgent task. It is clear that both the United States and the Soviet Union have nurtured the idea that it is possible to endure a nuclear war and survive it in some recognizable form despite the enormous loss of life and damage to the environment.

But what you have told us, and what the other witnesses here today have told us is that there may be far less chance for any kind of meaningful recovery, owing to the disruption and destruction of fundamental natural processes on which life as we know it depends—not to speak of political and economic reconstruction which would probably be just out of the question.

It should be a matter of urgent concern to the international community that this kind of scientific analysis go as far as possible toward establishing, on a solid foundation, the consequences to the global environment of nuclear war, and should be of equally great concern that this message be gotten across somehow to the leaders of governments possessing and seeking to possess nuclear weapons.

A prolonged international research effort, funded by governments and staffed by experts from the nuclear powers, reporting both to the public and to their governments, in my judgment, is clearly needed. At a time when virtually all other forms of scientific cooperation between the United States and the Soviet Union are at a standstill for political reasons, it might come as a welcome exception if these two governments were to jointly organize and sponsor such a research effort as a token of the seriousness with which they, as the possessors of these arsenals, view the threat which these arsenals pose to all mankind.

The testimony today can only lead reasonable people to conclude that there is no such thing as limited nuclear war, and that even contemplating a nuclear exchange, to use that phrase again, is pure lunacy. The facts as far as they have emerged indicate that, at best, we would bomb all humanity back to the Stone Age, and at worst, would destroy humanity and leave the planet a barren place. We cannot allow that to occur, and in the effort to insure that it does not, truth is the most powerful weapon. When the truth is obscured by uncertainty, there is a duty to remove that un-

certainty. We haven't removed all the uncertainties today, but we have circumscribed some of them and assessed the magnitude of some of them, and maybe they will yield to further research if we can focus a sustained research effort on an international basis.

I would like to thank you for helping us today, Dr. Von Hippel, and I would like to thank our other witnesses for the record. We will pursue this matter as a subcommittee.

With that, we will stand adjourned.

[Whereupon, at 4:16 p.m., the subcommittee was adjourned, subject to the call of the Chair.]

APPENDIX

JOHN F. FLY, CHAIRMAN
 ROBERT A. BYRNE, N.J.
 GEORGE I. BROWN, JR., CALIF.
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 BILL LOWERY, MISS.

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

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JOHN F. FLY, CHAIRMAN
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 BERTYNN W. BYRNELL, CALIF.

October 7, 1982

Mr. T. K. Jones
 Deputy Undersecretary of Defense
 (Strategic and Theater Nuclear Forces)
 The Pentagon
 Washington, D.C. 20301

Dear Mr. Jones:

On September 15, 1982, the Subcommittee on Investigations and Oversight held a hearing on the "Effects of Nuclear War on The Global Environment." Although the Department of Defense was invited to participate in the hearing, no witness was provided by the Department.

During the hearing, reference was made to a January 18, 1962, Los Angeles Times article in which you were quoted as saying that:

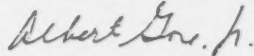
The United States would fully recover from an all out nuclear war with the Soviet Union in just two to four years, if it had a Soviet-style civil defense.

Because the statement attributed to you by the Los Angeles Times is at variance with the thrust of the testimony received at the hearing, we would be interested in reviewing any studies and/or analyses which led up to the statement. If your assessment has since changed and you now believe that recovery will require a longer period of time, we would also be interested in learning about the basis for such revised assessment.

For purposes of any response which you may wish to provide, we note that the Congressional Research Service has concluded that, if an all out nuclear war were to take place next year, the Soviet Union would be able to target 8453 strategic warheads comprising 6177 megatons at the U.S. and that the U.S. would have at its disposal 9828 strategic warhead comprising 3888 megatons. These force estimates were based on the assumption that both the U.S. and the U.S.S.R. would, through the end of the year, adhere to the SALT II Guidelines.

We will be holding the record open for the next three weeks and would appreciate your reply within that time. We look forward to including your response as well as our request into the record of the hearing. If you have any questions, please contact Mr. Jerry Ostrov or Robert E. Nicholas, Chief Counsel/Staff Director of the Subcommittee at 226-3636.

Sincerely,



Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

AG:JOK



OFFICE OF THE UNDER SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

OCT 29 1982

RESEARCH AND
ENGINEERING

28 October 1982

Honorable Albert Gore, Jr.
Chairman, Subcommittee on Investigations
and Oversight
Committee on Science and Technology
U.S. House of Representatives
Washington, D. C. 20515

Dear Mr. Chairman:

This is in response to your letter of October 7, 1982, regarding a statement attributed to me in a January 18, 1982, Los Angeles Times article.

I previously testified before the Congress on this matter at a hearing before the Senate Foreign Relations Committee on March 31, 1982, at which time I stated that I have not estimated the war recovery potential of the United States given a Soviet-type protection program. What I have done is to estimate the war recovery potential of the Soviet Union given Soviet plans and Soviet programs. My actual views on civil defense are as published in a subsequent issue of the Los Angeles Times, a copy of which is enclosed for your use.

I have, however, directed a major research program to assess the effectiveness of Soviet civil defenses. Early results of that work were reported in depth to the Joint Committee on Defense Production on November 18, 1976. Although it is true that Soviet recovery is influenced by U.S. megatonnage, the figures which you cite in your letter approximate the U.S. inventory, not that which might survive a Soviet attack and remain connected to the National Command Authority. Moreover, one might reasonably expect that most of the megatonnage which might survive and be usable would be directed at military targets, which would have only an indirect effect on Soviet economic recovery.

Sincerely,

D. K. Jones
Deputy Under Secretary
Strategic & Theater Nuclear Forces

Enclosure

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[illegible]

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P. O. Box 808, L-71
Livermore, California 94550

On September 15, 1982, the Subcommittee on Investigations and Oversight of the House Committee on Science and Technology held a hearing on "The Effects of Nuclear War on the Global Environment." At that time, Dr. James Friend provided the Subcommittee with estimates regarding the possible ozone depletion effects of nuclear war. Utilizing calculations obtained from you and an assumed total U.S. and Soviet nuclear force level of 13400 megatons, Dr. Friend advised the Subcommittee that the effect of detonating nuclear weaponry in such amounts would result in ozone depletion of 63%.

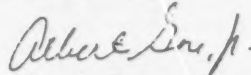
We understand that the force levels utilized by both you and Dr. Friend, i.e., the aggregate force figure of 13,400 megatons, was derived from a 1979 Office of Technology Assessment (OTA) study entitled, "The Effects of Nuclear War." A copy of the force scenario utilized in that study is attached to this letter and will be incorporated into the record of the hearing. Since the time of the OTA study, the Congressional Research Service (CRS) also has had occasion to estimate the size and composition of the U.S. and Soviet strategic nuclear forces. Thus, in its document "U.S./U.S.S.R. Strategic Offensive Weapons: Projected Inventories Based on Carter Policies," CRS provided year-by-year estimates through 1989 of the size of both the U. S. and Soviet forces. The CRS projections were based on two scenarios: adherence to the SALT II Guidelines; and non-adherence to the Guidelines.

On the assumption that the CRS data is more up to date than that used by OTA, we asked CRS to further update its data and present it in a distilled format similar to that found in the OTA study. The second set of tables accompanying this letter is the requested CRS update. The update is for the year 1983 and assumes adherence to the SALT II Guidelines. Note that CRS predicts a total of 10,066 megatons for both arsenals by the end of that year, as compared to the 13,400 megatons assumed in the 1979 OTA study.

We would appreciate it if you would evaluate the CRS tables. If in a format that lends itself to your calculations, we would welcome your projection as to the ozone depletion effects that would accompany a nuclear exchange of weapons comparable to those described in the CRS tables. Also, assuming weapon yield distributions comparable to those contained in the CRS tables, we would also be interested in your conclusions regarding ozone depletion were a strategic exchange to take place using a fraction (e.g., 50 or 75 percent) of the available weapons. Your response would be included in the record of the Subcommittee's September 15th hearing.

My staff has advised me of your assistance prior to the hearing for which I extend to you our sincere appreciation. We hope that, once again, you will be able to assist us with respect to the subject of this letter.

Sincerely,



Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

AG:JOK
Attachment

APPENDIX B—STRATEGIC FORCES ASSUMED

The strategic forces assumed to be available for an early to mid-1980's conflict between the United States and the Soviet Union are derived from open-source estimates of weapons characteristics and force levels. Generally, the forces are assumed to be within SALT II established limits and assume the completion of ongoing intercontinental ballistic missile (ICBM) modernization programs of both superpowers. For the United States this means that yield and accuracy improvements for the MXIII force are carried out. On the Soviet side, it means completing the deployment of their fourth-generation ICBMs, the SS-17, SS-18, and SS-19.

A recent study conducted by the Congressional Budget Office, entitled, "Counterforce Issues for the U.S. Strategic Nuclear Forces," provided table B-1, which shows Soviet forces and their capabilities for the early to mid-1980's.

Western estimates differ as to the exact attributes and capabilities of Soviet strategic systems. As a result some of the assumptions used in the studies drawn on for this report are mutually inconsistent. This would be an impor-

tant factor in an analysis of relative U.S. and Soviet military effectiveness, where the outcomes of a study would be very sensitive to the exact technical data used. In a study of the impacts of nuclear war on civilian population, however, a slight difference in the estimated yield or accuracy of a Soviet weapon will have no corresponding effect on the computation of the consequences of a given attack, relative to the degree of uncertainty that already exists in the prediction of those consequences.

U.S. estimates, on the other hand, are not subject to such great uncertainties. The Congressional Budget Office summary of U.S. forces is shown in table B-2.

It is useful to bear in mind that Soviet ICBM warheads are much higher in yield than their U.S. counterparts. While this has only a marginal impact on relative capabilities to destroy civilian targets on purpose, it means that Soviet attacks on U.S. targets will produce much more collateral damage (i.e. population casualties from attacks on economic targets, or economic and population damage from attacks on military targets) than will U.S. attacks on Soviet targets.

Table B-1.—Estimated Soviet Strategic Nuclear Forces, 1985

Launcher	Number ^a	Warheads per launcher ^b	Total warheads	Yield in megatons ^c	Total megatons	Equivalent megatons
SS-11	330	1	330	1.5	495	432
SS-17	200	4	800	0.8	480	560
SS-18	308	8	2,464	1.5	3,696	3,228
SS-19	500	6	3,000	0.8	2,400	2,580
SS-16	60	1	60	1.0	60	60
Total ICBMs	1,398		6,654		7,131	6,860
SS-N-6	600	1	600	1.0	600	600
SS-N-8						
SS-N-17	300	3	900	0.2	180	306
SS-N-18						
Total SLBMs	900		1,500		780	906
Bear	100	1	100	20	2,000	740
Bison	40	1	40	5	200	116
(Backfire)	(250)	(2)	(500)	(0.2)	(100)	(170)
Total bombers	140		140		2,200	856
	(390)		(640)		(2,300)	(1,026)
Grand total	2,438		8,294		10,111	8,622
	(2,688)		(8,794)		(10,211)	(8,792)

SOURCE: Counterforce Issues for the U.S. Strategic Nuclear Forces, Congressional Budget Office, January 1978.

Table B-2.—Estimated U.S. Strategic Nuclear Forces, 1985

Launcher	Number	Warheads per launcher	(Mid-1980's force)			Equivalent megatons
			Total warheads	Yield in megatons	Total megatons	
Minuteman II	450	1	450	1.0	450.0	450
Minuteman III	550	3	1,650	0.17	280.5	512
(with MK-12A)	(550)	(3)	(1,650)	(0.35)	(572.5)	(825)
Titan II	54	1	54	9.0	486.0	232
Total ICBMs	1,054		2,154		1,216.5 (1,508.5)	1,194 (1,507)
Poseidon	236	10	3,360	0.04	134	403
Poseidon C-4	160	8	1,280	0.10	128	282
Trident I	240	8	1,920	0.10	192	422
Total SLBMs	736		6,560		454	1,107
B-52 G/H	165	{ 6 SRAM { 4 bombs 20 ALCM 2 SRAM 2 bombs	990	0.2	198	337
B-52CM	165		660	1.0	660	660
B-52CM	165		3,300	0.2	660	1,122
FB-111	60		120	0.2	24	41
Total bombers	390		5,190		1,662	2,280
Grand total	2,180		13,904		3,332.5 (3,629.5)	4,581 (4,894)

SOURCE: Counterforce Issues for the U.S. Strategic Nuclear Forces, Congressional Budget Office, January 1978.

Which weapons would be used in our attack case? In Case 1, Detroit is targeted with a single warhead similar to those deployed on the multiple independently targetable reentry vehicle (MIRVed) SS-18 ICBM or with a large single weapon such as those carried by SS-9 or SS-18 Soviet ICBMs. Leningrad is targeted with yields approximately those of a Minuteman II warhead, a Titan II warhead, and all 10 reentry vehicles (RVs) from a Poseidon submarine-

launched ballistic missiles (SLBM). In Case 2, the U.S.S.R. attacks U.S. refinery targets with 10 MIRVed SS-18, warheads, and the United States attacks Soviet targets with a mix of Poseidons and Minuteman III, numbering 73 warheads. In Case 3, each side uses its most accurate MIRVed ICBMs against the other side's silos, and a mix of ICBMs, SLBMs, and bombers against bomber and missile submarine bases.

ESTIMATED 1983 INVENTORY OF DEPLOYED U.S. STRATEGIC OFFENSIVE WEAPONS
UNDER CURRENT SALT II GUIDELINES

<u>Delivery Vehicle (DV)</u>	<u>Number of DVs</u>	<u>Warheads Per DV</u>	<u>Sub-Total Warheads</u>	<u>Yield Per Warhead (MTs)</u>	<u>Sub-Total Yield (MTs)</u>
<u>ICBMs: 1/</u>					
Minuteman III (MK-12A)	300	3	900	0.335	301.5
Minuteman II (MK-12)	300 ^{2/}	3	900	0.17	153
Minuteman II	400 ^{2/}	1	400	1.2	480
Sub-Totals	1000		2200		934.5
<u>SLBMs:</u>					
Poseidon (19 Lafayette)	304	9 ave.	2736	0.40	1094.4
Trident I (12 Lafayette) (3 Ohio)	264 (192) (72)	8	2112	0.100	211.2
Sub-Totals	568		4848		1305.6
<u>Heavy Bombers:</u>					
B-52D	40 ^{3/}	2 SRAMs + 4 bombs	80 160	0.17 1.2 ave.	13.6 192
B-52G	100	4 SRAMs + 4 bombs	400 400	0.17 1.2 ave.	68 480
B-52G CMC	51	12 ALCMs + 4 SRAMs + 4 bombs	612 204 204	0.2 0.17 1.2 ave.	122.4 34.7 244.8
B-52H	90	4 SRAMs + 4 bombs	360 360	0.17 1.2 ave.	61.2 432
Sub-Totals	281		2780		1648.7
TOTALS	1849		9828		3888.8

1/ Titan II ICBMs are scheduled to be retired in 1982 and 1983.

2/ 50 of the 450 Minuteman II launchers have been authorized to be converted to launchers for Minuteman III. Consequently, the total number of Minuteman IIIs deployed will be 600 and the number of Minuteman IIs will drop to 400.

3/ B-52D bombers are scheduled to be retired starting in 1983. Currently, 75 B-52Ds are deployed.

ESTIMATED 1983 INVENTORY OF DEPLOYED SOVIET STRATEGIC OFFENSIVE WEAPONS

UNDER CURRENT SALT II GUIDELINES

<u>Delivery Vehicle (DV)</u>	<u>Number of DVs</u>	<u>Warheads Per DV</u>	<u>Sub-Total Warheads</u>	<u>Yield Per Warhead (MTs)</u>	<u>Sub-Total Yield (MTs)</u>
<u>ICBMs:</u>					
SS-18 (1 RV)	58	1	58	20	1160
SS-18 (8 RVs)	150	8	1200	0.9	1080
SS-18 (10 RVs)	100	10	1000	0.55	550
SS-19 (1 RV)	60	1	60	10	60
SS-19 (6 RVs)	300	6	1800	0.55	990
SS-17 (1 RV)	32	1	32	6	192
SS-17 (4 RVs)	120	4	482	0.75	361.5
SS-11 (1 RV)	518	1	518	0.95	492.1
SS-13 (1 RV)	60	1	60	0.6	36
Sub-Totals	1398		5210		4921.6
<u>SLBMs:</u>					
SS-N-20 (3 Typhoons)	60	10	600	0.2	120
SS-N-18 (15 Delta III)	240	7	1680	0.200	336
SS-N-17 (1 Yankee II) (3 SSBN-X)	60 (12) (48)	1	60	0.75	45
SS-N-8 (4 Delta II) (18 Delta I) (1 Hotel III)	286 (64) (216) (6)	1	286	0.8	228.8
SS-N-6 (19 Yankee I)	304	1	304	0.7	212.8
Sub-Totals	950		2930		942.6
<u>Heavy Bombers:</u>					
TU-95 Bear (Kamgaroo) (Bombs)	113 (75) (38)	1 4	227 (75) (152)	1.0 1.0	227 (75) (152)
Mya-4 Bison (Bombs)	43	2	86	1.0	86
Sub-Totals	156		313		313
TOTALS	2504		8453		6177.2

Lawrence Livermore National Laboratory

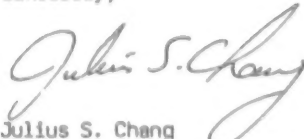
March 1, 1983

Representative Albert Gore, Jr.
Chairman
Subcommittee on Investigations and Oversight
Committee on Science and Technology
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Representative Gore:

Enclosed is a brief summary and related figures of our calculations on the potential impact of Salt II Guideline nuclear stockpile on stratospheric ozone. I am sorry that my early communication apparently was lost enroute. Please accept my apology for any inconvenience this may have caused you and your staff. I hope this is of some use to you and if we can be of further help on this important issue please feel free to contact us.

Sincerely,



Julius S. Chang
Theoretical Physics Division

JSC:nlw

enclosures

Effects of Hypothetical Exchanges of Strategic Nuclear Weapons Based on
Current Salt II Stockpile Guidelines

J. S. Chang and D. J. Wuebbles
University of California, Lawrence Livermore National Laboratory
Livermore, California 94550

A recent study (1982) by the Congressional Research Service estimates that under the current Salt II guideline the Soviet and U.S. stockpiles of strategic nuclear weapons will be significantly different from the earlier estimate of the Office of Technology Assessment (1979). In addition to differences in total yields, 13200 megaton (OTA) vs 10665 megaton (CRS), there are large differences in deployed weapons systems (Tables 1, 2, 3 and 4).

For the OTA (Tables 3 and 4) stockpile the theoretically estimate effect on stratospheric ozone due to several hypothetical exchange scenarios were reported in an earlier note (Chang, et al., 1982). We have now carried out calculations with six new hypothetical scenarios using the CRS estimates (Tables 1 and 2). The hypothetical scenarios are as follows:

- A. Allout exchange, all weapons successfully detonated.
- B. Only half of each type of weapons are successfully detonated.
- C. Only weapons with individual yields greater than 0.8 MT are used.
- D. Only weapons with individual yields less than or equal to 0.8 MT are used.
- E. Soviet stockpile only.
- F. U.S. stockpile only.

The estimated effect on total stratospheric ozone in the northern hemisphere from a detailed coupled chemical-transport model of the stratosphere are shown in Figs. 1 and 2. Briefly,

1. There are no significant difference in the time evolution of effects from previous analyses. In all cases maximum effects occurs in about six months and decays to less than 10% total ozone reduction within five years.
2. The maximum effect from the all-out exchange has changed from 63% to 51%. This is in direct proportion to the change in total yields from the OTA all-out scenario.
3. Due to saturation effect of the chemical system, halving the source (case B) does not lead to a factor of two less in effects.
4. Most of the damage (as much as 42% decrease out of 51%) to ozone layer is due to the high yield weapons, i.e., greater than 0.8 MT individual yields (case C).
5. Although almost half of the total yields are due to the less than or equal to 0.8 MT individual yield devices, they contribute less than 16% of the total 51% ozone decrease. This is mostly due to the low altitude of injected pollutants which leads to local ozone increases that compensated the upper level decrease (case D).
6. As far as the total stratospheric ozone is concerned the Soviet stockpile is about twice as destructive as the U.S. stockpile (Fig. 2).

Table 1

Estimated 1983 Inventory of Deployed Soviet Strategic Offensive WeaponsUnder Current Salt II Guidelines (CRS, 1982)

Delivery Vehicle (DV)	Number of DVs	Warheads Per Dv	Sub-Total Warheads	Yield per Warheads (MTs)	Sub-total Yield (MTs)
ICBMs:					
SS-18	58	1	58	20	1160
SS-18	150	8	1200	0.9	1080
SS-18	100	10	1000	0.55	550
SS-19	60	1	60	10	600
SS-19	300	6	1800	0.55	990
SS-17	32	1	32	6	192
SS-17	120	4	482	0.75	361.5
SS-11	518	1	518	0.95	492.1
SS-13	60	1	60	0.6	36
Sub-Totals	1398		5210		4921.6
SLBMs:					
SS-N-20	60	10	600	0.2	120
SS-N-18	240	7	1680	0.2	336
SS-N-17	60	1	60	0.75	45
SS-N-8	286	1	286	0.8	228.8
SS-N-6	304	1	304	0.7	212.8
Sub-Totals	950		2930		942.6
Heavy Bombers:					
TU-95 Bear	113	5	227	1.0	227
Mya-4 Bison (bombs)	43	2	86	1.0	86
Sub-Totals	156		313		313
TOTALS	2504		8453		6177.2

Table 2

Estimated 1983 Inventory of Deployed U.S. Strategic Offensive WeaponsUnder Current Salt II Guidelines (CRS, 1982)

<u>Delivery Vehicle (DV)</u>	<u>Number of DVs</u>	<u>Warheads Per Dv</u>	<u>Sub-Total Warheads</u>	<u>Yield per Warheads (MTs)</u>	<u>Sub-total Yield (MTs)</u>
ICBMs:					
Minuteman III	300	3	900	0.335	301.5
Minuteman II	300	3	900	0.17	153
Minuteman II	<u>400</u>	1	<u>400</u>	1.2	<u>480</u>
Sub-Total	1000		2200		934.5
SLBMs:					
Poseidon	304	9 ave.	2736	0.4	1094.4
Trident I	<u>264</u>	8	<u>2112</u>	0.1	<u>211.2</u>
Sub-Totals	568		4848		1305.6
Heavy Bombers:					
B-52D	40	2 SRAMs + 4 bombs	80 160	0.17 1.2 ave.	13.6 192
B-52G	100	4 SRAMs + 4 bombs	400 400	0.17 1.2 ave.	68 480
B-52G CMC	51	12 ALCMs + 4 SRAMs + 4 bombs	612 204 204	0.2 0.17 1.2 ave.	122.4 34.7 244.8
B-52H	90	4 SRAMs + 4 bombs	360 360	0.17 1.2 ave.	61.2 432
Sub-Totals	<u>281</u>		<u>2780</u>		<u>1648.7</u>
TOTALS	1849		9828		3888.8

Table 3

Estimated Soviet Strategic Nuclear Forces, 1985 (OTA, 1979)

Launcher	Number	Warheads per Launcher	Total Warheads	Yield in Megatons	Total Megatons	Equivalent Megatons
SS-11	330	1	330	1.5	495	432
SS-17	200	4	800	0.6	480	560
SS-18	308	8	2,464	1.5	3,696	3,228
SS-19	500	6	3,000	0.8	2,400	2,580
SS-16	<u>60</u>	1	<u>60</u>	1.0	<u>60</u>	<u>60</u>
Total ICBMs	1,398		6,654		7,131	6,860
SS-N-6}						
SS-n-8}	600	1	600	1.0	600	600
SS-N-17}						
SS-N-18}	<u>300</u>	3	<u>900</u>	0.2	<u>180</u>	<u>306</u>
Total SLBMs	900		1,500		780	906
Bear	100	1	100	20	2,000	740
Bison	<u>40</u>	1	<u>40</u>	5	<u>200</u>	<u>116</u>
Total bombers	140		140		2,200	856
GRAND TOTAL	<u>2,438</u>		<u>8,294</u>		<u>10,111</u>	<u>8,622</u>

Table 4

Estimated U.S. Strategic Nuclear Forces, 1985 (OTA, 1979)

Launcher	Number	Warheads per Launcher	(Mid-1980's Force)			
			Total Warheads	Yield in Megatons	Total Megatons	Equivalent Megatons
Minuteman II	450	1	450	1.0	450.0	450
Minuteman III	550	3	1,650	0.17	280.5	512
Titan II	54	1	54	9.0	486.0	232
Total ICBMs	1,054		2,154		1,216.5	1,194
Poseidon	336	10	3,360	0.04	134	403
Poseidon C-4	160	8	1,280	0.10	128	282
Trident I	240	8	1,920	0.10	192	422
Total SLBMs	736		6,560		454	1,107
B-52 G/H	165	6 SRAM	990	0.2	198	337
		4 bombs	660	1.0	660	660
B-52CM	165	20 ALCM	3,300	0.2	660	1,122
FB-111	60	2 SRAM	120	0.2	24	41
		2 bombs	120	1.0	120	120
Total bombers	390		5,190		1,662	2,280
GRAND TOTAL	2,180		13,904		3,332.5	4,581

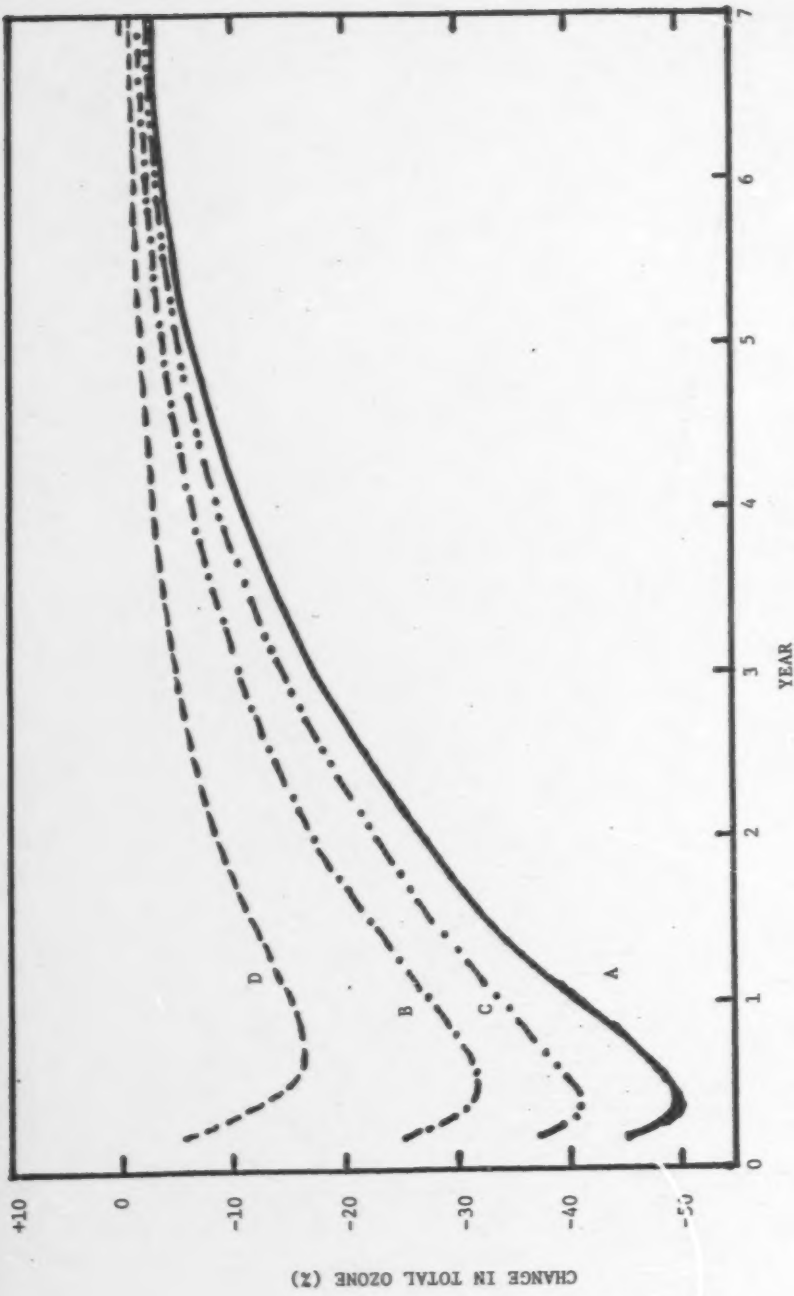


Figure 1: Percent total ozone change in the northern hemisphere for four different hypothetical nuclear exchange scenarios (see text).

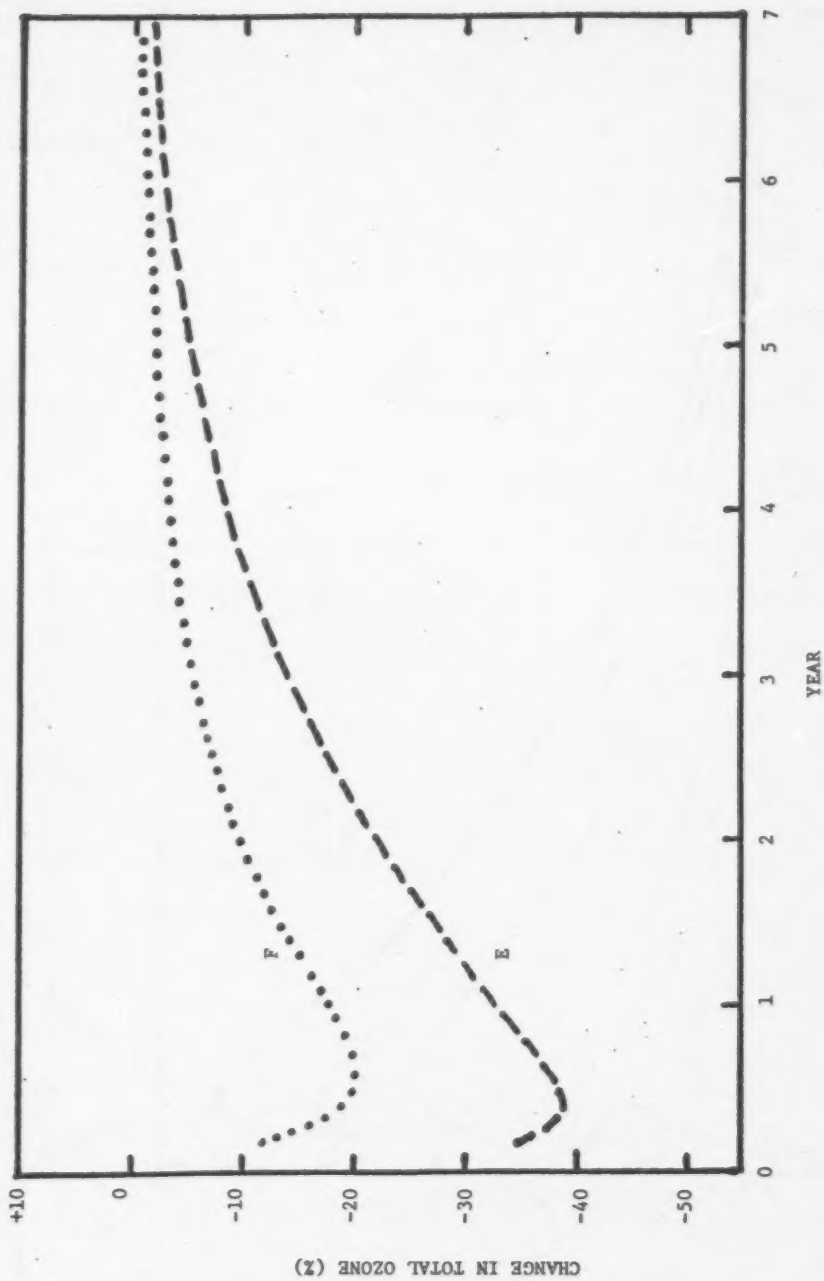


Figure 2: Percent total ozone change in the northern hemisphere (see text).

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RICHARD C. BENTLEY, JR., CALIF.
TOM MATTIN, IOWA
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JAMES J. BLANCHARD, ILL.
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DAN LUCHMAN, ILL.
ALBERT GORE, JR., TENN.
ROBERT A. YOUNG, MO.
RICHARD C. WHITE, TENN.
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COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

SUITE 2321 RAYBURN HOUSE OFFICE BUILDING

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October 8, 1982

HAROLD P. HANSON
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DANIEL B. BRAYCONE
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MINORITY STAFF DIRECTOR

Dr. Sidney D. Drell
Stanford Linear Accelerator Center
Stanford University
P.O. Box 4349
Stanford, California 94305

Dear Dr. Drell:

Thank you for giving testimony at the hearing on the Effects of Nuclear War on the Global Environment.

Prior to the hearing, the Subcommittee was aware of the immediate death toll that would take place in the event of a nuclear war. But, I don't think we had a full appreciation of the environmental and medical problems that would confront those who survived such a war. As a result of the hearing testimony, I believe that a nuclear war would inflict awesome destruction on the world's environment. Further, I do not believe that we can foreclose the possibility that such a war might place in jeopardy the very existence of those species that endured the initial destruction.

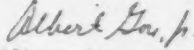
Through arms reduction initiatives and other proposals, I hope to reduce the likelihood that we will ever cross the nuclear firebreak. In this vein, a means must be found for conveying to the world's leaders the message which you and your colleagues brought to our Subcommittee. I am also convinced that a forum must be created for diligently pursuing those scientific questions that remain unanswered regarding the global consequences of a nuclear war. Because of the global dimensions of the issue, nothing short of an international effort is required to accomplish these two critical tasks. Accordingly, on October 1st, I called for an international year of research on the global consequences of nuclear war (see Enclosure.) As a focal point for the year's research activity, I also called for an international conference sponsored by the U. S. and the Soviet Union. In my view, such sponsorship is critical as an indication to the rest of the world of the earnestness with which the two superpowers view this important issue.

Translating the idea of an international year to the rest of the world body politic and to engage the support of the

world scientific community, many voices will have to rise in a collective plea for such an effort. I believe that your testimony before our Subcommittee is a major first step in that direction.

Again, thank you for testifying. Also enclosed with this letter are some supplemental questions for inclusion in the record. The Subcommittee would appreciate it if you would respond to these questions at your early convenience.

Sincerely,



Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

AG:JOK
Enclosures

Supplemental Questions

1. On page 6 of your prepared testimony, you note a number of serious problems with the concept of preparing for nuclear war through civil defense. In light of these problems, why do you believe that the Soviets spend large amounts on civil defense, and why do you believe that civil defense is promoted as a nuclear safeguard by certain quarters in this country?
2. On pages 3 and 4 of your prepared testimony, you speak of the many discoveries in the nuclear arena that have come by way of chance. Given that nuclear war cannot be reduced to laboratory size, how can we best resolve the uncertainties that remain and gain more information about the consequences of nuclear war?
3. Your testimony refers to the possibility of radioactive particles circling the Earth for months or years. Can you provide us with some indication of what such worldwide radiation levels might mean in terms of human or other biotic effects?

STANFORD UNIVERSITY

STANFORD LINEAR ACCELERATOR CENTER

NOV 8 1982
Mail Address
SLAC, P. O. Box 4349
Stanford, California 94305

November 4, 1982

The Honorable Albert Gore, Jr.
House of Representatives
Congress of the United States
Washington, D. C. 20515

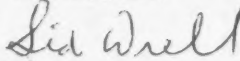
Dear Congressman Gore:

I am writing in response to your letter of October 8 which included three Supplemental Questions to my testimony of September 15, 1982, on "The Effects of Nuclear War on the Global Environment." Enclosed are my answers for inclusion in the Record of the Hearings.

I very much appreciate your efforts to spread understanding of the effects of a nuclear war. It is so vital that these be understood by leaders and citizens of the world. A well structured and prepared research program and an international conference, as you propose, can contribute to a better understanding of the global consequences of nuclear war. Certainly, the U.S. and the Soviet Union should work together toward improving our mutual understanding in this important area in which we face common dangers and share common interests.

I appreciated the opportunity to testify before your Subcommittee in these hearings. It was very nice meeting you.

Sincerely yours,



Sidney D. Drell
Professor and
Deputy Director

SDD:br

Enclosure

Sidney D. Drell
November 3, 1982

1. I don't know why the Soviets spend large amounts on civil defense, but, if they really believed in its effectiveness for surviving nuclear war, then I would expect them to be spending much more than at the current levels. Their present program is not an effective one for insuring their survival in the event of nuclear conflict. I agree with the following statements in the unclassified summary of the CIA analysis of "Soviet Civil Defense" (NI 78-10003, July 1978):

"Soviet measures to protect the economy could not prevent massive industrial damage. The Soviet program for dispersal of industry appears to be offset by a contrary tendency for investments in new facilities to be inside or near previously existing installations."

and

"We do not believe that the Soviets' present civil defenses would embolden them deliberately to expose the U.S.S.R. to a higher risk of nuclear attack."

There is currently no evidence to lead one to conclude that the Soviets would effectively implement a nationwide crisis evacuation. In particular, the Soviet Union has never tested a large-scale city evacuation, and there is no evidence that the Soviets can successfully execute nationwide crisis relocation. What the Soviets are known to have done is to build shelters for part of the work force and leadership and to have created a program for training of civil defense workers.

I think there are two general reasons behind the fact that civil defense is being promoted by certain quarters in this country. The first is a general feeling that one should do something to plan and prepare for survival in the face of the ever-present potential for disaster. However, for reasons given in my testimony, civil defense should not be viewed as substantially increasing the likelihood of survival or of recovery in a major nuclear war. Retargetting by the attacker can offset most of the life-saving potential of civil defense. With or without civil defense, the urban/industrial base - including most of the cities and key national production facilities - will be destroyed in a major attack. Civil defense does not offer a realistic escape from the current "balance of terror." The second reason comes from those who advocate extending the concept of deterrence to include the planning for waging and winning limited nuclear

conflicts. Such plans for "extended deterrence" require extensive civil defense preparations. I believe they are false illusions, however, as emphasized in my testimony.

2. I believe the primary uncertainties cannot be resolved. More modeling of effects on a global scale can help set some bounds on individual effects, but the most serious environmental and biological consequences can probably not be predicted since experiments to provide the necessary data are unthinkable. It would require a major nuclear exchange. It is important to recognize, as I tried to emphasize in my testimony, how extensive and important are the unknown factors that cannot be adequately anticipated.

3. An effort to answer this question was made in the fifth chapter, entitled "Other Long-Term Effects," of the excellent study, *THE EFFECTS OF NUCLEAR WAR*, prepared by the Congressional Office of Technology Assessment in 1979. I served on the Advisory Panel to this study, which was referred to in my testimony. To cite several conclusions of that study:

- "Cancer deaths in the millions could be expected during the 40 years following a large nuclear attack, even if that attack avoided targets in population centers. These millions of deaths would, however, be far less than the immediate deaths caused by a large attack on a full range of targets.
- "A large nuclear war could cause deaths in the low millions outside the combatant countries, although this would represent only a modest increase in the peacetime cancer death rate.
- "These results might not apply if an attacker set out deliberately to create very high radiation levels."

In addition to these, there are the incalculable effects which were reviewed in the 1975 report of the National Academy of Sciences on "The Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations." They were well summarized in the OTA report as follows:

- "It is possible that a large nuclear war would produce irreversible adverse effects on the environment and the ecological system.
- "In particular, it would not require very large changes to greatly diminish the production of food. The report notes that it would be

difficult to adapt to such changes in view of the likelihood that much of the world's expertise in agricultural technology might perish in the war.

- "The physical and biological processes involved are not understood well enough to say just how such irreversible damage, if it occurred, would take place.
- "Therefore, it is not possible to estimate the probability or the probable magnitude of such damage."

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COMMITTEE ON SCIENCE AND TECHNOLOGY
 U.S. HOUSE OF REPRESENTATIVES
 SUITE 2221 RAYBURN HOUSE OFFICE BUILDING
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 (202) 225-6371

October 8, 1982

Dr. H. Jack Geiger
 City College of New York
 School of Biomedical Education
 138th Street & Convent Avenue
 New York, New York 10031

Dear Dr. Geiger:

Thank you for giving testimony at the hearing on the Effects of Nuclear War on the Global Environment.

Prior to the hearing, the Subcommittee was aware of the immediate death toll that would take place in the event of a nuclear war. But, I don't think we had a full appreciation of the environmental and medical problems that would confront those who survived such a war. As a result of the hearing testimony, I believe that a nuclear war would inflict awesome destruction on the world's environment. Further, I do not believe that we can foreclose the possibility that such a war might place in jeopardy the very existence of those species that endured the initial destruction.

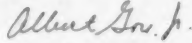
Through arms reduction initiatives and other proposals, I hope to reduce the likelihood that we will ever cross the nuclear firebreak. In this vein, a means must be found for conveying to the world's leaders the message which you and your colleagues brought to our Subcommittee. I am also convinced that a forum must be created for diligently pursuing those scientific questions that remain unanswered regarding the global consequences of a nuclear war. Because of the global dimensions of the issue, nothing short of an international effort is required to accomplish these two critical tasks. Accordingly, on October 1st, I called for an international year of research on the global consequences of nuclear war (see Enclosure.) As a focal point for the year's research activity, I also called for an international conference sponsored by the U. S. and the Soviet Union. In my view, such sponsorship is critical as an indication to the rest of the world of the earnestness with which the two superpowers view this important issue.

To bring the idea of an international year to the attention of the world body politic and to engage the support of the

world scientific community, many voices will have to rise in a collective plea for such an effort. I believe that your testimony before our Subcommittee is a major first step in that direction.

Again, thank you for testifying. Also enclosed with this letter are some supplemental questions for inclusion in the record. The Subcommittee would appreciate it if you would respond to these questions at your early convenience.

Sincerely,



Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

AG:JOK
Enclosures

Supplemental Questions

1. Will preparedness through civil defense help to mitigate any of the post-war difficulties you see?
2. We are told that the Soviet Union expends a much larger amount on civil defense than does the United States. Do you believe this to be the case? If so, can you speculate as to why the Russians believe civil defense will work? If there is any part of their civil defense program which you believe to be efficacious, would that component be useful to U.S. planners?

OCT 18 1982

THE CITY COLLEGE
OF
THE CITY UNIVERSITY OF NEW YORK
NEW YORK, N.Y. 10031

50

SOPHIE DAVIS SCHOOL OF
BIOMEDICAL EDUCATION

(212) 690-

October 13, 1982

The Honorable Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight
Committee on Science and Technology
U.S. House of Representatives
Suite 2321
Rayburn House Office Building
Washington, DC 20515

Dear Congressman Gore:

I am returning under separate cover the edited transcript of my testimony before the Subcommittee at the hearing on "The Effects of Nuclear War on the Global Environment".

What follows is my answer to the supplemental questions in your letter of October 8th.

1. Will preparedness through civil defense help to mitigate any of the post-war difficulties you see?

Answer: Not in any significant respect, and most probably not at all. The promise of civil defense is an illusion, and it offers no effective protection against the threat we face. It is difficult for people to understand this because it seems so natural and so prudent to prepare in advance for a potential disaster, and not to prepare seems like an abrogation of responsibility. But this disaster, as all of the testimony at your hearing demonstrated, is qualitatively and quantitatively so different from anything previous in human experience that "common sense" responses are meaningless. It is important that the uselessness of civil defense be made clear because this administration and others have spent so much time and money making false and unsubstantiated promises of protection through civil defense.

Civil defense will be useless for the following reasons:

1. The only major civil defense plan, crisis relocation from urban areas in a time of crisis, is unworkable and absurd. Most people know this. Even the Federal Emergency Management Agency concedes that it will require somewhere between three and eight days to accomplish, and obviously, such a relocation in the midst of crisis may precipitate the very war it is designed to protect against. Aside from the pragmatic difficulties of moving huge numbers of people, there is not a rational basis for deciding where they should be moved to. The so-called low risk areas are mere guesses, based on a presumed pattern of attack and all kinds of assumptions about wind direction, the pattern and distribution of fallout, weather conditions and the like. These are factors that cannot be predicted in advance, and as I indicated, crisis relocation may succeed in moving large numbers of people precisely into the areas of highest fallout risk.
2. There is no provision at present, nor could any such provision be made at realistic cost, for shelters to be made available to this huge population in so-called "low risk" areas. Such shelters, sufficient to house millions of people, would have to be inhabitable for at least two weeks and in most cases as long as four weeks, meaning that they would have to contain water, food, sanitary facilities, medical care, lighting, and all of the other necessities of life for millions of people inside or underground for that long at least.
3. As the testimony for your subcommittee made clear, even if crisis relocation works and all of these shelters (at a presumed cost of billions of dollars) had been prepared and worked effectively, the world in which these "survivors" emerged two or four or more weeks later would simply make survival unlikely for the vast majority. There would still be areas of dangerous-to-lethal radiation, severe malnutrition and infection, no assurance that food stocks would be safe, that crops would grow, that water would be uncontaminated, etcetera. The "survivors" will discover that they had simply traded immediate death in a nuclear attack for a slower death over a somewhat longer period of time.

4. There seems to be some presumption in civil defense planning that the primary target of a nuclear war would be populations, and that the objective is to destroy as many people as possible. Therefore, it seems to be reasoned, the evacuation of most people from "high risk" areas would cause an adversary to abandon his plans to attack. This seems to me to be nonsense. Targets in a nuclear war are first, an enemy's missiles, bomber bases, submarines, and military resources; second, an enemy's energy sources - oil fields, nuclear power plants, electric power plants and the like; third, an enemy's industrial capacity - which is to say, in the United States and the Soviet Union, the cities. They would be targets for destruction whether the inhabitants are there or have left. If, as I believe probable, they would be destroyed anyway, to what would the millions of evacuated "survivors" return? How would they be fed, housed, work, etcetera? The biological environment will be contaminated; the physical infrastructure will be destroyed, and the social fabric - all the means of cooperation and communication - will be ripped apart. The nation with the fewest survivors may in fact be best off after a nuclear attack because it will have something closer to a reasonable balance between available resources and the number of people. The more "survivors", the greater the imbalance.

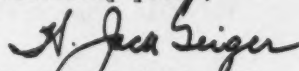
2. We are told that the Soviet Union expends a much larger amount on civil defense than does the United States. Do you believe this to be the case? If so, can you speculate as to why the Russians believe civil defense will work? If there is any part of their civil defense program which you believe to be efficacious, would that component be useful to U.S. planners?

Answer: There are, as you know, varying reports on the Soviet Union's expenditure for civil defense. Many of the claims simply seem to assert, without documentation, that there is a "civil defense gap", probably just as false as the so-called "missile gap", "margin of superiority", "window of vulnerability" and other similar false alarms. It should be noted that the Soviet Union faces a rather different set of threats than the United States - i.e., unlike us, they have to be concerned not only about nuclear war, but about the threat of conventional invasion either from NATO forces in the West or from China in the East. (It

has been remarked that "the Soviet Union is the only nation in the world entirely surrounded by hostile Communist powers". Some of their civil defense preparation may be designed to deal with conventional attack.) Crisis relocation plans, on their face, ~~which~~ seem to be absurd for the Soviet Union in view of that country's primitive highway system, transportation network, and other resources for the rapid movement of large masses of people. Finally, even assuming that all the reports of massive civil defense expenditures are true, which is unlikely, that is no reason to copy them. Why is it presumed that the Soviet Union is wise if it indulges in civil defense? We do not so presume with regard to their human rights policy, their system of government, their economy, their military planning, etcetera. There is no reason for us to do so in this area. The bottom line is, as the data clearly indicates, that civil defense cannot be an effective protection against nuclear war either in the United States or in the Soviet Union.

I hope these answers are helpful to you. Please let me know if there is any other information I can provide. It was a privilege to testify before your subcommittee, and I want to commend you for your efforts to place these facts before the public.

Sincerely yours,



H. Jack Geiger, M.D.
Arthur C. Logan Professor of
Community Medicine

HJG:tm

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SOPHIE DAVIS SCHOOL OF
BIOMEDICAL EDUCATION

February 9, 1983

(212) 690-

Hon. Albert Gore, Jr.
Subcommittee on Investigations and Oversight
Committee on Science and Technology
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Gore:

I am sorry to be so late in supplying the corrected version of my testimony before the subcommittee on the Effects of Nuclear War on the Global Environment. I hope it will still arrive on time to be useful.

Some of the answers to the two supplemental questions appeared at various points in my testimony and that of Dr. Drell. I have therefore supplied only brief additional answers below.

1. Will preparedness through civil defense help to mitigate any of the post-war difficulties you see?

Most of the public attention focussed on civil defense plans in the United States has addressed the issues of the practical absurdity of mass evacuation ("crisis relocation"), the unavailability of effective shelters (as well as food, sanitation, medical care and other necessities) in the so-called "safe" or host areas, and the fraudulence of the assurances of safety and effectiveness that have been offered by the Federal Emergency Management Agency and other civil defense proponents. Even if--in the face of all the available data--we grant FEMA, for the sake of argument, all of its premises and assume that there is a 5 to 7-day warning period, effective relocation and effective sheltering, the most that an all-out civil defense effort could do would be to shift the time of death and the nature of the fatal injury to most of the U.S. population. The civil defense calculation is that in the event of a major nuclear attack, without crisis relocation, 75 to 80 per cent of the U.S. population will die of trauma, burns and radiation injury within the first few days. Our analysis suggests that, in the event of such an attack, even with crisis relocation, 75 to 80 per cent of the U.S. population will be dead at the end of two years as a result of epidemic infectious disease, malnutrition and starvation, the residual effects of early trauma, and radiation injury.

The problem with civil defense/crisis relocation is not merely ineffectiveness, however. An ineffective disaster plan for the occurrence of an earthquake, a flood, a mass fire or some similar catastrophe does not, after all, increase the danger that the catastrophe will occur. In contrast, mass evacuation during a U.S.-Soviet crisis will be instantly detectable by satellite, may be interpreted as indicating that a first strike

AN EQUAL OPPORTUNITY EMPLOYER

is imminent, and may therefore precipitate the very event which it is intended to defend against.

2. We are told that the Soviet Union expends a much larger amount on civil defense than does the United States. Do you believe this to be the case? If so, can you speculate as to why the Russians believe civil defense will work? If there is any part of their civil defense program which you believe to be efficacious, would that component be useful to U.S. planners?

I have read a variety of figures alleged to represent Soviet expenditures on civil defense. Since this is outside my area of professional expertise, I have no basis for judging their accuracy. I am aware of the statement made a few years ago by Admiral Stansfield Turner, then the Director of our Central Intelligence Agency, to the effect that no civil defense effort so far undertaken in the Soviet Union could effectively defend that nation and that--more importantly--Soviet leadership could not possibly believe it would be effective.

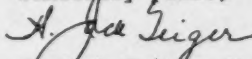
The civil defense problem faced by the Soviet Union is even more formidable than that confronting the United States, at least in terms of crisis relocation. Because of the unavailability of automobiles and necessary reliance on public transportation, Soviet cities are far more concentrated, and have far less suburban sprawl, than U.S. cities; this concentration makes the population more vulnerable to nuclear attack. In comparison with the U.S., the Soviet highway and transportation systems are primitive, making large population movements much more difficult.

But the real answer is that civil defense cannot provide effective protection in any modern industrial nation. The consequences of thermonuclear explosions are the same everywhere in the world; the laws of biology and physics do not vary; Russian flesh burns at the same temperature as American flesh, German children will get leukemia at the same bone-marrow radiation dose as English children, penetrating ultraviolet radiation will have the same effect on Canadian and Polish crops.

There are, in all probability, military and civilian officials in the Soviet Union who believe civil defense will work, just as there are in the United States. It does not seem to me to be sensible to match those alleged Soviet civil defense efforts just because they are being made. To do so would, in effect, be to contend that there is a "stupidity gap" which must be closed.

I hope these comments are helpful. Again, let me express my thanks for the opportunity to testify.

Sincerely yours,



H. Jack Geiger, M.D.
Arthur C. Logan Professor
of Community Medicine

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October 8, 1982

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BERNARD E. JENES

MINORITY STAFF DIRECTOR

Dr. Herbert L. Abrams
 Chairman, Department of Radiology
 Brigham and Women's Hospital
 25 Shattuck Street
 Boston, Massachusetts 02115

Dear Dr. Abrams:

Thank you for giving testimony at the hearing on the Effects of Nuclear War on the Global Environment.

Prior to the hearing, the Subcommittee was aware of the immediate death toll that would take place in the event of a nuclear war. But, I don't think we had a full appreciation of the environmental and medical problems that would confront those who survived such a war. As a result of the hearing testimony, I believe that a nuclear war would inflict awesome destruction on the world's environment. Further, I do not believe that we can foreclose the possibility that such a war might place in jeopardy the very existence of those species that endured the initial destruction.

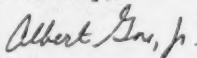
Through arms reduction initiatives and other proposals, I hope to reduce the likelihood that we will ever cross the nuclear firebreak. In this vein, a means must be found for conveying to the world's leaders the message which you and your colleagues brought to our Subcommittee. I am also convinced that a forum must be created for diligently pursuing those scientific questions that remain unanswered regarding the global consequences of a nuclear war. Because of the global dimensions of the issue, nothing short of an international effort is required to accomplish these two critical tasks. Accordingly, on October 1st, I called for an international year of research on the global consequences of nuclear war (see Enclosure.) As a focal point for the year's research activity, I also called for an international conference sponsored by the U. S. and the Soviet Union. In my view, such sponsorship is critical as an indication to the rest of the world of the earnestness with which the two superpowers view this important issue.

To bring the idea of an international year to the attention of the world body politic and to elicit the support of the

world scientific community, many voices will have to rise in a collective plea for such an effort. I believe that your testimony before our Subcommittee is a major first step in that direction.

Again, thank you for testifying. Also enclosed with this letter are some supplemental questions for inclusion in the record. The Subcommittee would appreciate it if you would respond to these questions at your early convenience.

Sincerely,



Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

AG:JOK
Enclosures

Supplemental Questions

1. During the hearing, we were advised by testimony of Professor Pitts that skin cancer could be a possible consequence of excess ultra violet radiation resulting from a depletion of the ozone layer. Would you agree that there is an association between excess ultra violet radiation and skin cancer? Assuming your answer is in the affirmative: At what level of ozone depletion would the risk of skin cancer become significantly greater than it is now and what might be the likely skin cancer expectancy rate? Given your testimony that medical supplies and staff would be in acutely short supply after a nuclear war, can you estimate what percentage of those contracting skin cancer would succumb to the disease?
2. You stated at page 23 of your testimony that deaths from communicable diseases among survivors could approach 20 - 25% and that, in a computer simulation of a nuclear attack 9 miles south of New Orleans, the fatality rate among survivors as a result of disease was estimated to be 35%. How would these estimates be affected if other possible environmental consequences of nuclear war were factored in? For example, what might be the synergistic effect of survivors, weakened by disease and radiation, having to endure weeks of reduced sunlight (testimony of Professor Birks) followed by a period of intense smog (Id.) followed by a two-year period of enhanced ultra violet radiation (testimony of Professor Friend)? Would you agree with the suggestion made during the hearing (testimony of Dr. Geiger) that, under such conditions, the potential for demographic recovery would seriously be brought into question?

HARVARD MEDICAL SCHOOL

DEPARTMENT OF RADIOLOGY

HERBERT L. ABRAMS, M.D.

*Philip H. Cook Professor
of Radiology**Chairman, Department of Radiology
Brigham and Women's Hospital*

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25 SHATTUCK STREET
BOSTON, MASS. 02115
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October 26, 1982

Congressman Albert Gore, Jr.
Chairman, Subcommittee
on Investigations and Oversight
Committee on Science and Technology
U.S. House of Representatives
Suite 2321
Rayburn House Office Building
Washington, DC 20515

Dear Congressman Gore:

May I express my appreciation to you for the opportunity to testify before your subcommittee. I cannot think of a more important area to explore and to inform ourselves, the public, and policy makers about than the medical and ecological consequences of nuclear war. I am persuaded that decisions are being made by our own government, and possibly by the Russians, based on the assumption that there is such a thing as "destructive advantage" in new and ever more powerful nuclear weapons. This is the message that comes through as we hear talk of preparing for protracted nuclear war in which we must prevail. The concept is that one side or the other can destroy the capacity of its adversary to respond in equivalently destructive fashion unless these new weapons are built. Hand in hand with this misconception -- a carryover from the period of conventional war when increased armaments might indeed have given a destructive advantage -- is the belief in something called "survivability" that is not as well-defined as it should be. What is not understood is that the more we continue to make destructive weapons, the greater the capacity of our adversaries to destroy and devastate this continent. Every action of ours in the nuclear field has had a reaction, and in the final analysis, as one looks at the curve of increasing stockpiles on the two sides, it is clear that the Russians will move aggressively if we embark on a new generation of destabilizing weapons, and that both superpowers' capacity to destroy their adversaries and themselves, and perhaps a major part of the planet, will be augmented.

The day of your hearing documented as well as possible that immediate biologic survival -- the death of "only" a

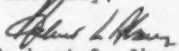
few hundred million -- by no means assures either social survival or extended physical survival. In answer to your second supplemental question, the 20 to 25% death rate from infectious and communicable disease in Year I by no means precludes a continued spread of infection in a highly susceptible population in the succeeding period. Much will depend on the intensity of fallout and the degree to which the immune mechanism is altered by radiation, but certainly the synergism of the ecological affects the difficulties of getting food and lodging even at the end of a year. The immense and draining problems of any kind of reconstruction, the change in ozone layer and possibly even in climate -- all of these would contribute to a weakened residue of individuals whose susceptibility to infection might well be sustained. My guess is that remnants of the species will survive, and may forage for food in the most primitive fashion, in a regression to a feudal era. Whether the survivors will be able to handle the psychological as well as the physical burdens are questions that cannot be answered explicitly.

In regard to the first question, I am in full agreement that there is an association between excess ultraviolet radiation and skin cancer. With a depletion of the ozone level to approximately 50%, and a profound shortening of the blistering time, the number of skin cancers could be expected to double and perhaps triple, although once again, it is impossible to adduce figures. In general, skin cancers can be treated by surgery or irradiation in the presence of a coherent medical care system, but the serious question is whether or not the medical resources to respond to malignant disease of any kind will be available to survivors.

Please let me know if there is anything I can do to support the concept and implementation of a year of research on the global consequences of nuclear war, as well as the international conference that you have suggested. I am a strong believer that a fully informed citizenry in this country and on the planet is a goal for which we must strive, and from which may emerge the kinds of pressures on the political process that force us and the Soviets to take some risks for nuclear peace. But the precondition for the solution of all other problems is clearly nuclear peace, and therefore it warrants at least a modest amount of attention from all of us.

Best regards.

Sincerely,


Herbert L. Abrams, M.D.

HLA/rs1

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October 8, 1982

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Professor Donald G. Pitts
 College of Optometry
 University of Houston
 Houston, Texas 77004

Dear Professor Pitts:

Thank you for giving testimony at the hearing on the Effects of Nuclear War on the Global Environment.

Prior to the hearing, the Subcommittee was aware of the immediate death toll that would take place in the event of a nuclear war. But, I don't think we had a full appreciation of the environmental and medical problems that would confront those who survived such a war. As a result of the hearing testimony, I believe that a nuclear war would inflict awesome destruction on the world's environment. Further, I do not believe that we can foreclose the possibility that such a war might place in jeopardy the very existence of those species that endured the initial destruction.

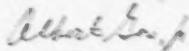
Through arms reduction initiatives and other proposals, I hope to reduce the likelihood that we will ever cross the nuclear firebreak. In this vein, a means must be found for conveying to the world's leaders the message which you and your colleagues brought to our Subcommittee. I am also convinced that a forum must be created for diligently pursuing those scientific questions that remain unanswered regarding the global consequences of a nuclear war. Because of the global dimensions of the issue, nothing short of an international effort is required to accomplish these two critical tasks. Accordingly, on October 1st, I called for an international year of research on the global consequences of nuclear war (see Enclosure.) As a focal point for the year's research activity, I also called for an international conference sponsored by the U. S. and the Soviet Union. In my view, such sponsorship is critical as an indication to the rest of the world of the earnestness with which the two superpowers view this important issue.

To bring the idea of an international year to the attention of the world body politic and to engage the support of the

world scientific community, many voices will have to rise in a collective plea for such an effort. I believe that your testimony before our Subcommittee is a major first step in that direction.

Again, thank you for testifying. Also enclosed with this letter are some supplemental questions for inclusion in the record. The Subcommittee would appreciate it if you would respond to these questions at your early convenience.

Sincerely,



Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

AG:JOK
Enclosures

Supplemental Questions

1. During your testimony, you noted that blindness in humans and animals would occur if the ozone layer were depleted by fifty percent. What is the risk that lesser depletion levels would produce blindness?
2. At a fifty percent ozone depletion level, how long could a person remain outdoors without being subject to serious eye damage or blindness?
3. Is there an ozone depletion threshold of say, ten percent, below which the risk of blindness is not significant? Would such a threshold be equally applicable to humans and animals?
4. During the hearing, we heard testimony that ozone depletion would be at its worst about six months after a nuclear war and that, once depleted, it would probably take up to two years for the ozone layer to reconstitute itself? Assuming the six month depletion level were sufficient to produce blindness, how long would the risk of blindness remain in effect?
5. During your testimony, you noted that other effects such as skin cancer might be associated with enhanced ultra violet radiation resulting from a depletion of the ozone layer. At what ozone depletion level might there be a significant risk of cancer, and how long an exposure would be required? How many times greater than the current risk of skin cancer might such risk be?



OCT 29 1982

University of Houston

Central Campus
Houston, Texas 77004

October 26, 1982

College of Optometry

The Honorable Albert Gore, Jr.
Chair Subcommittee on Investigations and Oversight
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Representative Gore:

The questions which have been presented to me will be answered with the following data in mind.

UV Radiation for Air Mass 1 (Konrath)

Wavelength in nanometers	Irradiance in Watts/cm ²
300-320	0.265×10^{-3}
320-400	5.22×10^{-3}

The radiant exposure for the production of UV induced cataracts is 0.15 J/cm^2 with a mean relative effectiveness of 0.028 and the radiant exposure threshold for photokeratitis 0.003 J/cm^2 with a mean relative effectiveness of 0.35. The normal environment at the earth's surface for sunlight is limited to 288nm by the ozone layer. Further, an aphakic eye has a retinal burn threshold at 325nm of 5 J/cm^2 . I shall now attempt to answer your questions.

Under normal sunlight conditions, there are $0.265 \times 10^{-3} \text{ W/cm}^2$ of UV irradiance available from the sun. Calculations show that the recommended exposure level of 1000 m J/cm^2 would be exceeded in approximately 1.0 hour for photokeratitis if the relative effectiveness were 0.003. The following table can be developed.

Table 1

Decrease in Ozone	Safe exposure duration
0%	1.0 hr
10%	54 min
30%	42 min
50%	30 min
75%	15 min

If the ozone depletion allows UV shorter than 288 nm to pass to earth the safe duration would be considerably reduced because it only takes 3 m J/cm^2 of 270 nm UV to

cause photokeratitis. If we assume that 30% of the space UV at 270 nm were transmitted to earth the following condition would occur. There 7.68×10^{-6} watts/cm² of UV radiation in a 10 nm waveband at 270 nm available on earth which would allow only 390 seconds or 6.5 minutes before photokeratitis would be experienced. For the 270 nm data the following table would be generated.

Table 2

<u>Decrease in ozone</u>	<u>UV irradiance on earth w/cm²</u>	<u>Safe exposure duration</u>
0%	0	indefinite
30%	0.8×10^{-5}	6.25 minutes
50%	1.3×10^{-5}	3.9 minutes
75%	1.92×10^{-5}	2.6 minutes

The duration of time to achieve threshold would be increased because a human does not look at the sun and it is estimated that the UV is about 10% effective. This means that the duration of allowable exposure would increase by up to a factor of 10. An exposure twice threshold ($2 \times H_C$) results in permanent damage.

Using these data, I shall attempt to answer the supplemental questions.

1. During your testimony, you noted that blindness in humans and animals would occur if the ozone layer were depleted by fifty percent. What is the risk that lesser depletion levels would produce blindness?

The risk is quite great. For example, Table 1 shows that the safe exposure duration is related to the UV above 290 nm which reaches earth and could be as little as 15 minutes or as long as 1.0 hour.

2. At a fifty percent ozone depletion level, how long could a person remain outdoors without being subject to serious eye damage or blindness?

Under normal conditions the 50% depletion of ozone would reduce the usual 1 hour exposure to 30 minutes (Table 1) but this could be as little as 3.9 minutes if wavelength at 270 nm were allowed to be transmitted to earth (Table 2).

3. Is there an ozone depletion threshold of say, ten percent, below which the risk of blindness is not significant? Would such a threshold be equally applicable to humans and animals?

If the ozone depletion allows UV below 290 nm, there would be no depletion below which blindness could potentially result (Table 2). It is my opinion that for durations of 30 minutes the human could learn to survive but animals could not survive. This means a steady depletion of animal stock unless the surviving human is knowledgeable enough to protect the surviving animals. The real answer is that humans are potentially at more risk but their intelligence and reasoning powers equates the risk for humans and animals.

4. During the hearing, we heard testimony that ozone depletion would be at its worst about six months after a nuclear war and that, once depleted, it would probably take up to two years for the ozone layer to reconstitute itself? Assuming the six month depletion level were sufficient to produce blindness, how long would the risk of blindness remain in effect?

The risk of blindness would remain in effect until the ozone depletion recovered sufficiently for the UV to be screened from reaching the earth in amounts quite close to our present environmental conditions. This means until the ozone depletion were restored - unless the surviving humans know the cause of the damage.

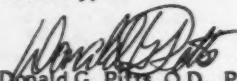
5. During your testimony, you noted that other effects such as skin cancer might be associated with enhanced ultraviolet radiation resulting from a depletion of the ozone layer. At what ozone depletion level might there be a significant risk of cancer, and how long an exposure would be required? How many times greater than the current risk of skin cancer might such risk be?

It has been unequivocally stated that for each 2% increase in UV radiation (UV-B) reaching the earth there will be a corresponding 1% increase in skin cancer. This would be a 50% increase in risk which would vary according to the UV available. In the USA, 25% of all malignant lesions are skin cancers and it causes more than 5000 deaths each year. The skin cancer results from chronic exposure to sunlight. The action spectrum range is 290 nm to 325 nm with the 300 to 310 nm waveband the most effective. Epstein et al (Pg. 552 of reference) have shown that 0.122×10^{-2} J/cm² (12.2×10^{-5} ergs/cm² of 280-320 nm) three times a week for 12 months causes cancer in albino and pigmented mice. If we were to accept this data as the value for human cancer, Table 1 shows the 300 to 320 wavelength range to produce 0.265×10^{-3} W/cm² on earth and the duration to achieve 1.22×10^{-2} J/cm² with emphasis on the skin would be 46 seconds, however, this level would require 8 hrs x 3 days x 52 weeks or 1248 exposure hours (44.9×10^3 sec). A decrease in ozone by 50% would reduce the exposure duration to half the normal time.

I hope this information proves helpful in your evaluation.

References: (See The Biologic Effects of UV Radiation, F. Urbach, Ed, Pergamon Press, N.Y., 1969).

Sincerely,


Donald G. Pitts, O.D., Ph.D.
Professor, Physiological Optics
and Optometry

DGP/ter

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October 8, 1982

Professor John W. Birks
 Department of Chemistry and Cooperative
 Institute for Research in Environmental Sciences
 University of Colorado
 Campus Box 449
 Boulder, Colorado 80309

Dear Professor Birks:

Thank you for giving testimony at the hearing on the Effects of Nuclear War on the Global Environment.

Prior to the hearing, the Subcommittee was aware of the immediate death toll that would take place in the event of a nuclear war. But, I don't think we had a full appreciation of the environmental and medical problems that would confront those who survived such a war. As a result of the hearing testimony, I believe that a nuclear war would inflict awesome destruction on the world's environment. Further, I do not believe that we can foreclose the possibility that such a war might place in jeopardy the very existence of those species that endured the initial destruction.

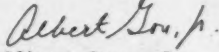
Through arms reduction initiatives and other proposals, I hope to reduce the likelihood that we will ever cross the nuclear firebreak. In this vein, a means must be found for conveying to the world's leaders the message which you and your colleagues brought to our Subcommittee. I am also convinced that a forum must be created for diligently pursuing those scientific questions that remain unanswered regarding the global consequences of a nuclear war. Because of the global dimensions of the issue, nothing short of an international effort is required to accomplish these two critical tasks. Accordingly, on October 1st, I called for an international year of research on the global consequences of nuclear war (see Enclosure.) As a focal point for the year's research activity, I also called for an international conference sponsored by the U. S. and the Soviet Union. In my view, such sponsorship is critical as an indication to the rest of the world of the earnestness with which the two superpowers view this important issue.

To bring the idea of an international year to the attention of the world's public and to engage the support of the

world scientific community, many voices will have to rise in a collective plea for such an effort. I believe that your testimony before our Subcommittee is a major first step in that direction.

Again, thank you for testifying. Also enclosed with this letter are some supplemental questions for inclusion in the record. The Subcommittee would appreciate it if you would respond to these questions at your early convenience.

Sincerely,



Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

AG:JOK
Enclosures

Supplemental Questions

1. On page 3 of your testimony, you note that the U. S. Forest Service has made estimates regarding the amount of forest acreage that would be burned in the event of a nuclear attack. Could you provide us with the source of your information?
2. On page 4 of your testimony, you note that ozone concentrations in the Northern Hemisphere, at ground level, could approach five times normal concentrations for months following a nuclear war. Could you tell us what health and ecological consequences could flow from such levels?
3. On page 5 of your testimony, you note the possibility of significant ozone depletion effects at a war level of 10,000 megatons, but no depletion effects under the war scenario (5742 megatons) assumed by Ambio magazine. (We are incorporating the war scenario table used by Ambio into the record of the hearing.) Would your conclusions regarding the Ambio scenario have changed if the scenario had assumed that multiple weapons in the one-half to one megaton size range were to be targeted on certain points of interest?
4. On page 6 of your testimony, you note the possibility of climate changes as a result of nuclear war. You also caution that these might be difficult to assess. Could you tell us what form the climatic changes might take and what their consequences might be? Do you believe that additional research would provide more insight into some of these uncertain areas?

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November 2, 1982



NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

Representative Albert Gore, Jr.
Chairman, Subcommittee on Investigations
and Oversight
Committee on Science and Technology
U.S. House of Representatives
Suite 2231 Rayburn House Office Building
Washington, D.C. 20515

NOV 11 1982

Dear Mr. Gore:

I am in full support of your call for an international study of the global effects of a nuclear war. I believe that this would be an excellent way to focus world attention on this crucial problem and am willing to help in any way.

In your letter of October 8 you pose some additional questions arising with regard to my testimony. My answers to these questions follow:

1. Question: On page 3 of your testimony, you note that the U.S. Forest Service has made estimates regarding the amount of forest acreage that would be burned in the event of a nuclear attack. Could you provide us with the source of your information?

Answer: This statement is based on footnote #4 of page 3 of the Journal of the Federation of American Scientists. The footnote reads: "In the late fifties, Dr. John N. Wolfe stated that an attack of 1,446 megatons would start so many fires as to seriously disrupt post-attack agriculture. But Dr. J.E. Hill suggested, in testimony to U.S. Congress (Civil Defense, 1961), that the effects of such an attack might not be any more serious than the combined effects of forest fires that occurred in the United States from 1930 to 1931. Much depends upon weather conditions. The U.S. Forest Service agreed with Hill if the conditions were least favorable to firespread and the fires died out. In the case of maximum spread, however, with favorable conditions for fire, the estimates of burned land would expand from 138,000 square miles to 2,406,000 or 81 percent of the land area of the coterminous United States!"

2. Question: On page 4 of your testimony, you note that ozone concentrations in the Northern Hemisphere, at ground level, could approach five times normal concentrations for months following a nuclear war. Could you tell us what health and ecological consequences could flow from such levels?

Answer: Our model indicated that ozone levels would increase to levels as high as 160 parts-per-billion. These are longitudinal averages, and since the sources of the pollutants are

on land, we expect that the actual levels on the continents would be much higher. Human subjects have not been purposely exposed to such high levels for long periods of time because of the toxic effects of ozone at those levels. The threshold for observable physiological effects appears to be below 100 parts-per-billion. Ozone causes respiratory difficulty, nausea and headache. The Environmental Protection Agency has established a maximum exposure of 120 parts-per-billion for one hour once each year as a standard that should not be exceeded. Other animals may be more or less sensitive to ozone exposure. Much more work is required in this area.

Present ozone levels of about 30 parts-per-billion have been found to be sufficiently high to cause significant reduction in crop yields. The Environmental Protection Agency has established a National Crop Loss Assessment Network to determine more accurately the loss of crops as a result of air pollution. Crops grown in large open top chambers were subjected to various levels of ozone 7 hours per day during the entire course of their growing season. The results of these studies were recently published (Journal of the Air Pollution Control Association, Vol. 32, pp 353-361, 1982). The relationship between yield reduction and ozone concentration was found to be linear. The highest levels tested were 100 parts-per-billion of ozone. Extrapolation of their data to 160 parts-per-billion gives the following results for % Yield Reduction of various crops: Soybeans 64%, Winter Wheat 42%, Corn 15%, and Peanuts 99%. This is for exposure to ozone only 7 hours per day. Thus, it seems likely that continuous exposure to 160 parts-per-billion ozone would result in virtually total elimination of all crops. Of course, ozone would affect all other plant life, possibly having disastrous ecological consequences. Not enough is known at this point to be more quantitative.

3. Question: On page 5 of your testimony, you note the possibility of significant ozone depletion effects at a war level of 10,000 megatons, but no depletion effects under the war scenario (5742 megatons) assumed by Ambio magazine. (We are incorporating the war scenario table used by Ambio into the record of the hearing.) Would your conclusions regarding the Ambio scenario have changed if the scenario had assumed that multiple weapons in the one-half to one megaton size range were to be targeted on certain points of interest?

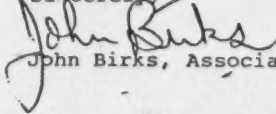
Answer: Yes, it is quite possible that the explosion of several weapons in the same general area within a short time period would result in the deposition of the oxides of nitrogen formed at higher altitudes. This would then cause an increase in the degree of ozone depletion in the stratosphere.

4. Question: On page 6 of your testimony, you note the possibility of climate changes as a result of nuclear war. You also caution that these might be difficult to assess. Could you tell us what form the climatic changes might take and what their consequences might be? Do you believe that additional research would provide more insight into some of these uncertain areas?

Answer: In answer to this question I would like to quote from an article recently written by A. B. Pittock of the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia. The article summarizes our results reported in AMBIO and provides some additional considerations: "In view of the many complex effects and uncertainties indicated above, the climatic effects can only be speculated upon at this time. They could, however, be appreciable. For a first scenario (the Ambio scenario) type war the main effects would be tropospheric. In the first few weeks the hemispheric pall of dust, smoke and gaseous infra-red absorbers might lead to very stable conditions in the troposphere, with most incoming solar energy being absorbed in the upper troposphere (5-10 km. altitude) instead of at the ground. A hemisphere-wide inversion layer might form with reduced vertical mixing and ventilation at the surface, and reduced meteorological activity. Evaporation would be decreased markedly and, together with a large increase in cloud condensation nuclei, this might cause a reduction in the size of cloud water droplets and in precipitation. This could slow down the rate of removal of tropospheric pollutants, thus prolonging the effects, and cause a more uniform distribution of radioactive fallout. A dirty radioactive smog, enveloping much of the northern hemisphere, could persist for many weeks leading to a marked short-term climatic anomaly. In the case of a second scenario type war, or one in which much NO was injected into the stratosphere by anti-ballistic missiles (Crutzen and Birks 10,000 Mt scenario), the additional oxides of nitrogen, mainly as NO₂, would cause significant heating below 22 km altitude, while reduced O₃ concentrations would lead to cooling above 22 km. This would tend to destabilize the stratosphere, with unknown effects on the global circulation, and also could cause more NO to be carried up into the photochemically active region from below, or down from the upper stratosphere if it were injected there by high altitude nuclear explosions. This enhanced vertical transport of NO could increase the destruction of ozone. Widespread changes in the surface albedo might be expected both in the short and long term. Initially a large fallout of soot and other particulates could darken many high albedo surfaces including snow and ice fields, perhaps leading to widespread melting and positive temperature feedbacks. In the longer run, fire, phytotoxicity and radioactive fallout may also kill off large areas of vegetation leading to albedo changes and perhaps to desertification in marginal areas with the onset of a biogeophysical feedback as suggested by Charney et al. (Science, Vol. 187, pp 434-5, 1975)."

The climate of the earth is affected by numerous variables and involves feedback systems that are difficult to model. It is entirely possible that we have so far overlooked the most important effect of a nuclear war on the earth's climate. Certainly additional study would provide more understanding of this problem.

Sincerely,



John Birks, Associate Professor

RESPONSE TO FURTHER QUESTIONS

J. P. FRIEND

Question: What should be done to provide more accurate assessments of atmospheric and other effects?

Answer: Construed narrowly, the question in the context of nuclear war, concerns two effects: the change of climate caused by 1) alteration of atmospheric chemical processes and 2) the prolonged presence of aerosols in the stratosphere and troposphere. In the case of aerosols, the fundamental physical processes of the interactions with radiation are well-known. The difficulty lies in determining the magnitudes of the subsequent effects of other parts of the climate system. For example, how will the altered radiation affect the amounts of evaporation, precipitation, and cloud cover? And beyond that, how will those changes in turn affect the amounts of (the already altered) radiation? To answer these and many other such pertinent questions we need accurate quantitative knowledge.

The incorporation of our knowledge of atmospheric chemical processes into climate models is, as I have indicated in my statement, probably the most important need for the assessment of climate changes resulting from chemical perturbations such as NO injections into the stratosphere, the spread of smog from massive hydrocarbon releases, and the long-term release of chlorofluorocarbons. For some chemistry/climate problems we do not have sufficient knowledge of the basic chemical processes, as is the case for acid precipitation, e.g.

When we consider that the threats to our environment such as nuclear war, increasing the carbon dioxide content of the atmosphere, the enhancement of acidity in precipitation and the depletion of ozone by release of chemicals

and increased use of fertilizers, we have three general areas of concern:

1. climate change
2. chemical contamination of the surface
environment (soil, water, plants, animals)
3. increases in damaging radiation (solar u.v.
and nuclear).

I indicated (in answering a question) that the research in the biological effects of increased solar radiation is sorely needed for making more accurate assessments of environmental threats. Experts at the 1981 National Academy of Sciences workshop concerning biological effects considered that the present state of knowledge is inadequate for providing anything but the crudest sort of distinction between negligible effects and extremes of damage. A major need here is for a broad attack on the fundamental processes which cause the damage and their quantification in the form of action spectra for each process. The NAS report "Causes and Effects of Ozone Reduction: An Update", 1982, lists the needs in detail.

The U.S. has a national climate program mandated by Congress (H.R. 10013). Under it a vigorous program of climate research was established and coordinated by the Secretary of Commerce. Under the present Administration there has been a significant cut in some agencies' budget's for climate research - particularly NASA, which is limited to conducting research only in the radiation aspects and in modeling and is funded at what has been described to me as "survival level". In light of the obvious importance of the understanding of climate to the assessment of environmental threats, it is clear to me that anything short of vigorous and expanding support at the national level is not acceptable. that is what is needed to ensure headway being made. The goal of understanding climate is one of the great challenges

to scientists and the attainment of that goal will surely be a major benefit to humankind.

Question: In what other areas does further work need to be done to eliminate the large uncertainties in estimating effects of nuclear war?

Answer: As I mentioned above, the other area most in need of new fundamental knowledge is in radiation biology - namely, the effects of enhanced solar radiation on the biosphere, which includes humans, domestic animals, agricultural plants, and all natural flora and fauna and their ecosystems.

Question: What do you think of the idea of an international symposium or conference to illuminate the problems of nuclear war effects?

Answer: I think such a forum would be an unparalleled opportunity to raise global awareness of the facts, issues and problems surrounding nuclear war effects. Until the present most of the nations of the world have been content to let the U.S. conduct scientific research in most of the areas of importance - particularly in the effects related to ozone reduction. Certainly the establishment of an international study year could lead to significant new information on the basic problems discussed by me on climate and biospheric effects. It could serve to stimulate thinking and research in other countries and it could reinforce the need for doing more here.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

October 8, 1982

Professor James P. Friend
Department of Chemistry
Drexel University
Philadelphia, Pennsylvania 19104

Dear Professor Friend:

Thank you for giving testimony at the hearing on the Effects of Nuclear War on the Global Environment.

Prior to the hearing, the Subcommittee was aware of the immediate death toll that would take place in the event of a nuclear war. But, I don't think we had a full appreciation of the environmental and medical problems that would confront those who survived such a war. As a result of the hearing testimony, I believe that a nuclear war would inflict awesome destruction on the world's environment. Further, I do not believe that we can foreclose the possibility that such a war might place in jeopardy the very existence of those species that endured the initial destruction.

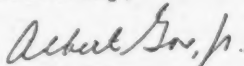
Through arms reduction initiatives and other proposals, I hope to reduce the likelihood that we will ever cross the nuclear firebreak. In this vein, a means must be found for conveying to the world's leaders the message which you and your colleagues brought to our Subcommittee. I am also convinced that a forum must be created for diligently pursuing those scientific questions that remain unanswered regarding the global consequences of a nuclear war. Because of the global dimensions of the issue, nothing short of an international effort is required to accomplish these two critical tasks. Accordingly, on October 1st, I called for an international year of research on the global consequences of nuclear war (see Enclosure.) As a focal point for the year's research activity, I also called for an international conference sponsored by the U. S. and the Soviet Union. In my view, such sponsorship is critical as an indication to the rest of the world of the earnestness with which the two superpowers view this important issue.

To bring the idea of an international year to the attention of the world body politic and to engage the support of the

world scientific community, many voices will have to rise in a collective plea for such an effort. I believe that your testimony before our Subcommittee is a major first step in that direction.

Again, thank you for testifying. Also enclosed with this letter are some supplemental questions for inclusion in the record. The Subcommittee would appreciate it if you would respond to these questions at your early convenience.

Sincerely,



Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

AG:JOk
Enclosures

Supplemental Questions

1. Is there a point at which the atmosphere becomes saturated by the ozone-depleting effects of nuclear war? If so, is it possible that a depletion factor approximating the 63% level referred to at page four of your testimony could be reached at a force level smaller than the 13,400 megatons assumed in your testimony?
2. On page 4 of your testimony, you indicate that the possibility of climate change from nuclear war is "nonnegligible" and that such effects may be irreversible. You also note that modeling some of these climatic effects is difficult and that our ability to model the compositional effects of such changes has not improved much since 1975. What are some of the adverse consequences that might be precipitated by war-induced climate changes? How can we better our knowledge in this area so that the state of the art is advanced from where it was in 1975?
3. In addition to climatic effects, what other atmospheric effects of nuclear war might yield new information if subjected to further inquiry?

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U.S. HOUSE OF REPRESENTATIVES
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WASHINGTON, D.C. 20515
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October 8, 1982

Professor Arthur H. Westing
Dean of Faculty, School of Natural Science
Hampshire College
Amherst, Massachusetts 01002

Dear Professor Westing:

Thank you for giving testimony at the hearing on the Effects of Nuclear War on the Global Environment.

Prior to the hearing, the Subcommittee was aware of the immediate death toll that would take place in the event of a nuclear war. But, I don't think we had a full appreciation of the environmental and medical problems that would confront those who survived such a war. As a result of the hearing testimony, I believe that a nuclear war would inflict awesome destruction on the world's environment. Further, I do not believe that we can foreclose the possibility that such a war might place in jeopardy the very existence of those species that endured the initial destruction.

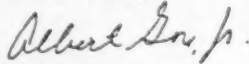
Through arms reduction initiatives and other proposals, I hope to reduce the likelihood that we will ever cross the nuclear firebreak. In this vein, a means must be found for conveying to the world's leaders the message which you and your colleagues brought to our Subcommittee. I am also convinced that a forum must be created for diligently pursuing those scientific questions that remain unanswered regarding the global consequences of a nuclear war. Because of the global dimensions of the issue, nothing short of an international effort is required to accomplish these two critical tasks. Accordingly, on October 1st, I called for an international year of research on the global consequences of nuclear war (see Enclosure.) As a focal point for the year's research activity, I also called for an international conference sponsored by the U. S. and the Soviet Union. In my view, such sponsorship is critical as an indication to the rest of the world of the earnestness with which the two superpowers view this important issue.

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world scientific community, many voices will have to rise in a collective plea for such an effort. I believe that your testimony before our Subcommittee is a major first step in that direction.

Again, thank you for testifying. Also enclosed with this letter are some supplemental questions for inclusion in the record. The Subcommittee would appreciate it if you would respond to these questions at your early convenience.

Sincerely,



Albert Gore, Jr.
Chairman
Subcommittee on Investigations
and Oversight

AG:JOK
Enclosures

Supplemental Questions

1. On page three of your testimony, you refer to the possibility of long term climate effects as a result of fine particles of dust and water being thrust into the air from multiple nuclear blasts. Is there any way of predicting the magnitude of such effects and what the consequences might be? Assuming some uncertainty in this area does exist, is it an area that would profit from further research?
2. On page 4 of your written testimony, you state that ozone depletion as a result of nuclear war would not be confined to the Northern Hemisphere. Could you describe more fully the phenomena that might cause depletion effects to be felt in the Southern Hemisphere? Would the effects be as severe as in the Northern Hemisphere?
3. On page 4 of your testimony, you state that, if plankton lying close to the surface of the ocean were killed as a result of ultra violet radiation, the oceanic food chain would be largely broken. Can you tell us what the likelihood is that plankton would be damaged by ultra violet radiation from nuclear war? Would this area benefit from further research?
4. On page 4 of your statement, you note that, only considering the effects from excess ultra violet radiation, as much as 20% of the world's plants could be lost as a result of nuclear war. Would many of these plants be food crops? In general, what are some of the ecological consequences of a plant life diminution of this order? Would such plants be able to reseed and grow back in later years?
5. On page 5 of your testimony, you note the possibility of crop contamination from radiation. At what level of radiation (in rads, with rem equivalents) might such contamination take place. Would areas far away from the site of an attack suffer crop damage as a result of fallout?

Hampshire College

Amherst, Massachusetts / 01002

15 October 1982

Mr. Albert Gore, Jr.
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Gore:

Thank you for your kind and informative letter of 8 October which, inter alia, outlines your commendable efforts in minimizing the possibility of a future nuclear war. I respond to your five specific questions below.

1a. How one can predict the effect on climate of dust thrust into the stratosphere: Both the NAS study (Nier et al., 1975) and the SIPRI study (Westing, 1977) approach this matter by comparing the impact of dust injected into the stratosphere by volcanic action with that by a possible nuclear war. However, the uncertainties here are many. It is difficult to estimate the amount of dust that, e.g., Krakatoa injected; it is difficult to estimate this for a nuclear ground burst; and it is difficult to determine the effect that volcanic (or bomb) dust will have on the climate. Considerably more theoretical (modelling) and other research is called for here in order to be able to refine our estimates in this regard.

1b. The same question for water: Although it can be calculated that large quantities of water would be injected into the atmosphere by nuclear explosions, the climatic or other environmental effects of such perturbation have not been studied in any detail, at least there is no evidence of this in the open literature. Prof. E.J. Sternglass (University of Pittsburgh) has given some preliminary thought to the matter and may publish his conclusions in the future. Here again, some detailed research is needed.

2. The reason for ozone depletion being distributed globally: The ozone depletion effect occurs largely in the lower stratosphere (i.e., above the tropopause) where there are no jet streams or other turbulent movement of the atmosphere. The intruded oxides of nitrogen and the resulting depletion of ozone would thus become distributed equally in all directions by diffusional movement and without regard to the equator. In time, the effect would become essentially equalized throughout the world.

3. The likelihood of marine plankton destruction by UV: The state of apropos scientific knowledge is extraordinarily scanty here and this likelihood can thus not be predicted with any satisfactory degree of certainty. I believe that I have referred to all of the key references on the subject (see my page 4, paragraph 3) and they add up to very little. It is clear that research is desperately needed in this area, especially research carried out under natural conditions.

4. The level of food crop destruction by UV: Again, our state of scientific knowledge is dismally limited here. The best recent analytical review of the subject (Caldwell, 1981) attests to this pitiful state. My best guess is that of the order of 20% of our food crop plants (as of all of our plants) would succumb, perhaps on a global basis. This would result in a major, unprecedented upheaval of the world's natural and agricultural ecosystems. Ecological recovery would be by the slow replacement of the killed vegetation in the denuded and erosion-debilitated areas by UV-hardy species (probably of an inferior sort at least in human terms).

5. Extent of intolerable radioactive fallout contamination of food crops: This contamination would be confined to large areas surrounding surface bursts, and largely downwind from them. These contaminated areas would probably remain intolerable for decades. The U.S. Arms Control and Disarmament Agency (ACDA, 1978) has estimated that a U.S. attack upon the USSR would do this to 35% of its rural area. An attack by them on us would presumably do the same or worse. The overall extent of such contamination would, of course, depend upon the size and number of ground bursts and their distribution, among other factors. If the attack were designed to do so, then the entire country could be thus contaminated.

Again let me say that I was very pleased to have been able to testify before your Committee on Science and Technology, Subcommittee on Investigations and Oversight and thereby contribute in some small measure to your important endeavors.

With best wishes, I remain

Sincerely yours,

Arthur H. Westing
Arthur H. Westing
Professor of Ecology

P.S. Enclosed you will find a copy of my letter of 16 September that requests reimbursement of \$311.60 for my expenses related to testifying on 15 September.

Reference Scenario: How A Nuclear War Might Be Fought

AMBIO

VOLUME XI NUMBER 2-3 1982

The purpose of this article is to present the assumptions about a nuclear war which provide the basis for the other articles in this issue, in the form of a scenario describing how and where nuclear explosions might occur. This form of presenting the basic assumptions was chosen for two reasons. First, the various environmental effects of a global nuclear war would interact with each other in a number of ways; in order to describe how those interactions might occur, and in order to make the conclusions of the articles comparable, it is necessary to have a common set of assumptions, which are those contained in this "reference scenario." Second, presentation of the possible dimensions of a nuclear war in the form of a scenario makes the consequences of such a war more accessible, in all their horror, to readers outside the community of professional scientists.

This basic scenario has been designed to generate the major consequences of a global nuclear war, and their interactions with the environment. It does not try to describe the most probable nuclear war, and it is not intended to serve as the basis of a discussion of defense planning. In order to generate the likely environmental effects of a nuclear war, this scenario is more catastrophic than that envisioned by many defense planners.

However it is clear that a nuclear war, even if limited to a relatively small part of the devastation imagined in this scenario, would still be catastrophic enough. For the purposes of this publication, we have assumed that less than half of the total explosive power in the Soviet and American nuclear arsenals will be used—perhaps not the most likely of the nuclear war scenarios, but one chosen as an interesting alternative upon which to base the articles in this issue. Many people believe that any use of nuclear weapons will escalate into a war in which all or most of the weapons in the nuclear arsenals are used, which is why there are scenarios much more catastrophic than this one in the literature.

It is possible that a nuclear conflict would not escalate to the degree shown here, but would be limited, for example, to one city on each side being destroyed. It is also possible that once a nuclear exchange begins, neither side would surrender while a significant portion of its arsenal remains intact. History shows that in the highly emotional atmosphere of war, countries do not surrender under such circumstances—they usually fight on to the bitter end. Since political leadership, command, control and communications centers will be priority targets, some believe that a nuclear war would be virtually impossible to control once it begins. The environmental, social, economic, and health effects of the "limited" scenario presented here are devastating; the effects of an all-out nuclear war would be unimaginably more disastrous.

This scenario assumes that a global nuclear war breaks out at about 11 AM New York time, 6 PM Moscow time, on a weekday in early June, 1985. By this date one side or the other may have developed and deployed sufficiently accurate nuclear weapons and enough first-strike technologies to make its political and military leaders less cautious about using its nuclear forces. Moreover, the superpower rivalry in some areas of the world, like the Persian Gulf, may by then be at an unprecedentedly dangerous level. And a domestic political upheaval may occur at any time in one, or more, countries in say, the Gulf region. The mid-1980s are therefore likely to be a dangerous period for world security.

A nuclear world war is likely to escalate rapidly. A war in a Third World region could spread to Europe. A European war may start with conventional weapons but is likely to escalate to a nuclear war as soon as one side penetrates far into the other's territory. Specifically, nuclear weapons are likely to be used if the weapons themselves are in danger of being overrun by the enemy. Given that nuclear artillery has a range of less than 20 kilometers, this could happen rather soon after the outbreak of war.

A nuclear war may begin with the use of tactical nuclear weapons, targeted behind the enemy lines and against large targets, like airfields, vehicle storage areas, communication centers, and so on, but is then likely to escalate to a large-scale exchange of strategic nuclear weapons. These escalating steps would probably follow one another over a relatively short period of time—days rather than weeks. Because the consequences of a nuclear world war are unlikely to depend significantly on this time-span, our scenario assumes for simplicity that both sides fire their nuclear weapons in rapid succession.

In 1985 the USA will have a total of about 2840 strategic nuclear warheads (of which 8175 will be independently targetable), with a total explosive power of about 6510 megatons. The Soviet Union will have about 1310 strategic nuclear warheads (of which 10480 will be independently targetable), with an explosive power of about 140 megatons; or if the new Soviet ICBM has a 15 megaton warhead the total megatonnage will be 8641. For our purposes we assume a reasonable figure would be 5000 megatons. The US and Soviet tactical nuclear arsenals each contain roughly 2200 megatons, and the number of tactical nuclear warheads is about 35 000. Thus the total megatonnage in both sides' strategic and tactical arsenals would be ca 12 800.

The problem with any scenario of a nuclear world war is to choose a set of targets for fifty to sixty thousand nuclear warheads. There is so much overkill in the arsenals that the exercise becomes overwhelming. It is impossible to find "reasonable" targets for all of these. In our "limited" scenario, we have only targeted 14 737 warheads, comprising less than half the megatonnage in the 1985 arsenals, or about 6750 megatons. According to one strategist, Desmond J Ball, the US strategic targeting plans include 40 000 designated targets in the USSR for 9000 warheads in the American strategic nuclear arsenal. This allows flexibility in the choice of targets. The targets according to Ball include: 20 000 military targets in the



Fallout patterns for population centers in North America according to Ambio's scenario.

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USSR: 15 000 economic-industrial targets; 2000 targets (mostly cities) to kill the Soviet leadership; and 3000 targets associated with the Soviet nuclear forces.

In March 1980, the US Defense Department gave the following examples of targets in each set.

1. Soviet nuclear forces

Intercontinental and intermediate-range ballistic missiles, together with their launch facilities and launch command centers

Nuclear weapons storage sites

Airfields supporting nuclear-capable aircraft

Bases for submarines firing nuclear missiles

2. Conventional military forces

Casernes

Supply depots

Marshalling points

Conventional air fields

Ammunition storage facilities

Tank and vehicle storage yards

3. Military and political leadership

Command posts

Key communications facilities

4. Economic and industrial targets

a. War-supporting industry

Ammunition factories

Tank and armored personnel carrier factories

Petroleum refineries

Railway yards and repair facilities

b. Industry contributing to economic recovery

Coal

Basic steel

Basic aluminum

Cement

Electric power

In this reference scenario North America, Europe and the Soviet Union are regarded as the main strategic areas in a nuclear war, although a number of other countries are considered important for strategic and political purposes. The great powers might decide to target some countries to prevent them from dominating international politics following a nuclear war. For example, this scenario includes targets in Latin America, despite the Tlateloco Treaty, which prohibits the placement of nuclear weapons in that area.

The Soviet warheads are targeted mainly on North America, Europe and China, which is a more widespread and complicated pattern of targets than that of the US, whose targets are mainly concentrated in the Soviet Union.

There are three categories of targets in this scenario: population targets, military targets and economic/industrial targets. It should be noted that military and economic/industrial targets are often located in or near cities.

Nuclear explosions at ground level have different effects from weapons exploded in the air. This scenario assumes that bombs detonated at ground level will maximize the number of casualties from local fallout, but will greatly reduce the number of immediate deaths from the effects of blast. The division between ground and air bursts chosen in this scenario differs from that assumed in most other descriptions of nuclear war. The effect is to emphasize in this scenario the immediate environmental impact of the explosions.

Cities in the USA, Canada, Western Europe, Eastern Europe, the USSR, Japan, North and South Korea, Vietnam, Australia, South Africa and Cuba are targeted with the following megatonnages (ground bursts):

a) Cities with 100 000–1 million people: 1 megaton (three 300-kiloton warheads, one 100-kiloton warhead)

b) Cities with 1 million–3 million people: 3 megatons (three one-megaton warheads)

c) Cities with 3 million or more people: 10 megatons (ten 500-kiloton, five one-megaton warheads)



Fallout patterns for population centers in Europe according to Ambio's scenario.

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Cities with populations of 500 000 or over in China, South-East Asia (except Vietnam and North and South Korea), India, and Pakistan are targeted with the following megatonnages (ground bursts):

- a) Cities from 500 000–1 million people: 1 megaton (three 300-kiloton warheads, one 100-kiloton warhead)
- b) Cities with 1 million–3 million people: 3 megatons (three one-megaton warheads)
- c) Cities with 3 million or more people: 10 megatons (ten 500-kiloton warheads, five one-megaton warheads)

Cities will use up a total of 4970 warheads and 1941 megatons. Of the strategic warheads, 4845 are targeted on cities in the Northern Hemisphere.

Most industry in the countries directly involved in the nuclear war will be destroyed with the cities. We have targeted—with air bursts—the remaining important industries, energy supplies, and mineral resources in these countries, and in other areas of the Northern and Southern Hemispheres. This uses up another 3136 warheads and 701 megatons.

There are, of course, a very large number of possible military targets. Many of these are in, or close to, cities. In addition to these, we show the airfields and ports in

the Northern and Southern Hemispheres likely to be attacked, targeted with ground bursts. This would use up 6620 warheads and 2960 megatons. Twenty-one warheads and 140 megatons were used to close straits.

This brings the total number of warheads used to 14 747, and the total megatonnage used to about 5742 megatons. The Northern Hemisphere receives 5569 megatons, while the Southern Hemisphere receives 173 megatons (Table 1).

In this scenario we have chosen three categories of targets—urban, military and economic. Targets of equal importance in the most strategic areas of the world, the US, the USSR and Europe, have been dealt with on the same "category" basis. For example, all cities with a population of 100 000 or more in these areas are targeted with the same levels of megatonnage. This is also true of military and economic targets, whether they are located in North America, Europe or the USSR. We have not, for example, targeted USSR military bases of lower priority than those targeted in the US or in Europe.

Due to the sheer numbers of targets in the categories outlined above, more goals have been identified for USSR warheads than for US warheads. As a result the USSR expends more of its warheads and megatonnage in this scenario than does the

US. If lower-priority targets were to be identified in the USSR than in the other two major areas, then the damages to the USSR would of course be correspondingly greater.

The total megatonnage devoted to different target categories in the scenario (population centers, military targets, economic targets) was calculated in the following way.

1. Megatonnage for all relevant population targets was calculated first.
2. Megatonnage for military targets which did not duplicate population targets was calculated next.
3. Megatonnage for economic targets which did not duplicate population targets or economic targets was then calculated. The resulting figures are shown in Table 1-C.

In preparing the maps showing the distribution of the early fallout from the warheads targeted on population centers (see Maps 1–4) we have taken the weather on a particular day—June 10, 1980—as a starting point. The direction of the individual fallout plumes follows the direction of the wind at an elevation of about 5 kilometers above sea level. Differences in the speed of the wind have been disregarded; an average value of 25 kilometers per hour

has been used everywhere. The influence of precipitation on the fallout pattern has not been taken into account. The resulting idealized fallout plume is the one shown in the map. The plumes are drawn to show areas which would receive at least 450 rad. One half of the people receiving a whole-body dose of about 450 rad (air dose) will die within a month or so. The size of the plume enclosing areas which receive more than 450 rad is approximately 20 by 145 kilometers (13 x 90 miles) for a 1-megaton bomb. Even though three 300-kiloton warheads and one 100-kiloton warhead are used to reach the 1 megaton figure, for simplicity's sake the plume is drawn as though a 1 megaton warhead was used; this would tend to underestimate the extent of areas which receive 450 rad. Plumes for 3-megaton and 10-megaton targets are drawn on a similar basis.

Since the wind patterns may change very significantly from one day to the next it may seem a rather arbitrary assumption to use the winds of a particular day. However other possible devices, such as using climatological average winds or the most common wind direction and speed for each place, would not have resulted in a fallout pattern more representative than that illustrated here.

Obviously the details of the fallout pattern shown in the maps are very uncertain and might have been very different had the weather of another day been chosen. We believe, however, that the overall picture is fairly realistic. The fact that the plume for each individual target has been drawn independently of the other targets in the neighborhood implies a certain underestimation of the areas covered by lethal fallout. A certain location which is not covered by a plume may still receive more than 450 rad if the contributions from two or more nearby targets are added together. This means that for regions which are hit by many bombs the area actually receiving more than 450 rad is appreciably greater than that indicated on the map. In order to take some of their effect into account we have drawn dashed lines around areas which we estimate to have been completely covered by 450 rad. The "delayed fallout" remaining after one month and after ten years is given in Table 2.

OTHER POSSIBLE TARGETS

Beyond the targets mentioned in the reference scenario, some authors have chosen to consider targets in three additional categories: nuclear power reactors, nuclear submarines, and explosion of nuclear devices in outer space.

Nuclear Power Reactors

If a nuclear reactor is hit by a nuclear bomb, the radioactivity contained in the reactor will be dispersed together with the radioactivity produced by the bomb itself.

Since the reactors contain relatively small amounts of short-lived compounds compared to those produced by the bombs, their contribution to the total dose rate during the first few weeks after the detonation will be only modest. However the amounts of the more long-lived compounds ^{90}Sr and ^{137}Cs contained in nuclear reactors are very substantial, and the long-term radioactivity from the reactors will be very significant compared to that from the bombs.

The difference in decay rates between the total radioactive material produced by a one-megaton thermonuclear bomb and that contained in a one Gigawatt nuclear reactor is illustrated in Figure 1.

Table 3 shows areas for several values of accumulated dose for the same periods as in Figure 2. In Western Europe, where many reactors are in operation and many more are being built or planned, an attack on them would make practically the whole of these and neighboring countries unin-

Table 1. Warheads and megatonnage, Reference Scenario.

A.		
Total number of warheads used: 14 747		
Total megatonnage used: 5742 Mt		
Megatonnage used in Northern Hemisphere: 5169 Mt		
Megatonnage used in Southern Hemisphere: 173 Mt		
B.		
Size of warheads	Number used	
100 kt	939	
200 kt	2930	
300 kt	4410	
500 kt	5692	
1 Mt	769	
10 Mt	7	
C.		
Numbers of warheads used for different target categories.		
Megatons used for different target categories:		
Military targets:	6620 warheads	2960 Mt
Population (1124 cities):	4970 warheads	1941 Mt
Industry/Energy	3136 warheads	701 Mt
Closing of straits (14 straits)	21 warheads	140 Mt
Warheads used for different target categories:		
D.		
Military	300 kt	(one 300-kt warhead per target)
	100 kt	(one 100-kt warhead per target)
	200 kt	(one 200-kt warhead per target)
ICBM		(two 500-kt warheads per silo)
Submarine Bases		(one 1-Mt warhead per base)
Population	1 Mt	(three 300-kt + one 100-kt per city)
	3 Mt	(three 1-Mt warheads per city)
	10 Mt	(ten 500-kt + five 1-Mt warheads per city)
Industry	1 Mt	(five 200-kt warheads per site)
Oil fields	1 Mt	(two 500-kt warheads per site)
Closing of straits	10 Mt	(seven 10-Mt + fourteen 500-kt warheads)
		(this is total for the 14 straits)
E.		
Military targets.		
Megatonnage per target (average)		
Air bases	300 kt	ground burst
Naval ports	300 kt	ground burst
Army bases	300 kt	ground burst
Command/control/radar	300 kt	ground burst
Early warning systems	100 kt	ground burst
SOSUS	300 kt	water burst
ICBM	Two 500 kt warheads per silo	ground burst
Energy Resources targets:		
Hydro electric stations	10 kt	airburst
Other energy resources	10 kt	airburst
Oilfields	1 Mt	airburst
Industrial targets:		
(only large industrial complexes)		
Oil refineries	1 Mt	airburst
Chemical plants	1 Mt	airburst
(heavy organics, urea/nitric acid, sulfuric acid, ammonia)		
Cement	1 Mt	airburst
Iron ore/steel	1 Mt	airburst



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Local (early) fallout from bombs on nuclear reactors. The shaded areas correspond to a dose of 100 rad (1 Gy) at 1 year starting one month after the detonation. Other assumptions are the same as those for Map 1. The sites have been divided into 5 categories according to the output of the reactors on the site: from up to 1 GWe to 5 and more GWe. The directions of the plumes have been determined from the direction of the wind at the site. In reality, the plumes would follow the wind and be curved accordingly.



habitable by ordinary standards of radiation safety for years or decades. The same would be true for North America and Japan. Such an attack would also seriously upset planned civil defense measures.

The contours in the reactor maps represent the areas which would receive 100 rads (1 Gy) within a year, starting one month after the detonation of a 1 Mt bomb on each reactor site. A dose of 100 rads is significantly less than the LD₅₀ dose, used in Map 1 (450 rads) but it is still 1000 times the natural background radiation—a high dose by the normal standards of radiation safety.

Should a nuclear weapon be exploded on a reprocessing plant or a storage tank the uninhabitable areas would be even greater, and they would remain so for a longer period because the activity in these plants or tanks is even longer-lived than that in a reactor. As an example, the last

column of Table 3 shows the areas covered by doses received in one year, starting one month after the explosion of a 1-Mt bomb on a storage tank of a capacity of about 3000 cubic meters.

The delayed fallout after one month of ⁹⁰Sr and ¹³⁷Cs and ¹³¹I as illustrated for the reference scenario in Table 2 (column a) would be increased by only 30 to 40 percent even if all the nuclear reactors of the world were hit. However the deposit remaining after ten years would be three to four times higher if the reactors were included in the scenario.

Nuclear Submarines
Developments in anti-submarine warfare are proceeding rapidly, and by 1985 it may be possible to accurately target nuclear submarines. Approximately 45 submarines (30 from the US, 15 from the USSR, or half of the projected 1985 fleets) might be targeted, each with a warhead of 500 kilo-

tons or less. The submarines would probably be attacked in waters of 800 meters depth or more. See map 2 for hypothetical but possible locations. The blasts would be water-bursts, with practically no global fallout, since most of the radioactive material would fall back into the oceans. Radioactive fog-spray might drift over coastal areas, however.

Radioactive fission products might also be released from the reactors of nuclear-powered submarines and surface vessels. There are about 320 large nuclear-powered submarines and about 10 nuclear-powered surface warships currently in operation. In a nuclear war, the nuclear-powered ships at sea might be sunk with torpedoes, depth charges, or anti-ship missiles equipped with nuclear warheads. It is highly probable that the nuclear reactors of the ships sunk would be ruptured.

Table 2. Deposit of radioactivity ("delayed fallout") (a) one month and (b) 10 years after the war (Reference Scenario). Unit: Ci/km².

Latitude	(a) After 1 month			(b) After 10 years			Area x 10 ³ km ²
	⁹⁰ Sr	¹³⁷ Cs	¹³¹ I	⁹⁰ Sr	¹³⁷ Cs	¹³¹ I	
90°-60°N	0.04	0.07	2	0.1	0.1	-	34
60°-40°N	0.7	1.1	60	0.7	1	-	57
40°-20°N	0.2	0.3	15	0.3	0.4	-	77
20°-Equator	0.04	0.05	2	0.1	0.1	-	87
Northern Hemisphere average	0.25	0.4	20	0.3	0.4	-	255
Equator-20°S	0.01	0.01	0.5	0.03	0.04	-	87
20°-40°S	0.01	0.01	0.7	0.03	0.04	-	77
40°-60°S	0.02	0.04	1.5	0.04	0.06	-	57
60°-90°S	-	-	-	0.02	0.03	-	34
Southern Hemisphere average	0.01	0.02	0.7	0.04	0.05	-	255
Global average	0.2	0.2	10	0.2	0.2	-	510

Notes

Number of bombs of different tonnages/latitude band according to Table 1.

Emission yields:

⁹⁰Sr : .06 MCi/Mt fission yield

¹³⁷Cs : 12 "

¹³¹I : 80 "

Reference: Sources and Effects of Ionizing Radiation. Report of the United Nations Committee on the Effects of Atomic Radiation. United Nations (New York, 1977). Height of emissions according to Figure 11 Rotblat and Barnaby, pg. 93. Ground bursts assumed to deliver 50 percent of the radioactivity in local fallout (not included in the table). Air bursts give no local fallout.

Tropospheric emissions assumed to be deposited in same latitude belt and within one month. Stratospheric emissions distributed along the latitudes according to observed ⁹⁰Sr in soils (Ref. M W Meyer, Nature 219:566, 1966). Deposition after one month corresponds to tropospheric emissions only (with due regard to decay of ¹³¹I) but without the local fallout which is given on Map 1. Deposition after 10 years corresponds to the total delayed fallout in emissions in both troposphere and stratosphere (with due regard to decay).

In reality, the fallout cannot be expected to be distributed evenly within each latitude band. Certain regions, not necessarily in the immediate vicinity of the detonations, may receive a fallout up to ten times higher than the average values given in this table.

It is seen from Table 2 that the delayed fallout is highest in the mid latitudes of the northern hemisphere where most of the detonations take place. After one month the radioactivity is dominated by ¹³¹I. Ten years later all the ¹³¹I has decayed and the long-lived isotopes ⁹⁰Sr and ¹³⁷Cs dominate. Despite their decay, the deposits of ⁹⁰Sr and ¹³⁷Cs are higher after ten years than after one month. This is because a substantial fraction of the radioactive material is injected into the stratosphere and remains there several years before it is brought to the ground. For the same reason the fallout after ten years is also more evenly distributed over the globe.

A typical nuclear-powered submarine carries a reactor generating about 60 megawatts (thermal) and produces about 40 grams of fission products per day of operation; a nuclear-powered surface warship may have a reactor of about 250 megawatts (thermal), and produces about 160 grams of fission products per day. If its reactor were ruptured, a nuclear submarine which had been at sea for a month before it was sunk would release long-lived fission products originating from about 1.2 kilograms of original fission products, roughly equivalent to the amount released by a 25-kiloton atomic bomb. A nuclear-powered warship which had been at sea for three months before it was sunk would release roughly the same amount of long-lived fission products as a 300-kiloton fission bomb. (For more details see *Warfare in a Fragile World*, Taylor and Francis/SIPRI, 1978 London).

Outer Space

A number of 1 Mt weapons might be detonated in outer space at an altitude greater than 40 km during the first day of hostilities as a method of disrupting communications. The electromagnetic pulse resulting from the explosions would affect electrical power supplies and electronic equipment, including radio and television. Most military equipment would be shielded against the pulse, but civilian installations would not be, and civil defense programs might be disrupted. There would be no radioactive fallout on the earth as a result of these explosions, and the effect on the ozone layer would also be minimal. (See Crutzen and Birks, p 114).

This Reference Scenario was compiled by AMBIO's group of advisers for this issue. The group included: Dr Frank Barnaby, Professor of Peace Studies at the Free University of Amsterdam; Dr Joseph Rotblat, Emeritus Professor of Physics at the University of London and founder of the Pugwash Conference on Science and World Affairs; Henning Rodhe, Professor of Chemical Meteorology at the Arrhenius Laboratory, University of Stockholm; Dr Lars Kristoferson, Scientific Program Officer of the Beijer International Institute for Energy and Human Ecology, Jan Prawitz, special assistant for disarmament to Sweden's Minister of Defense; and Jeannie Peterson, Editor of AMBIO (currently on leave of absence).

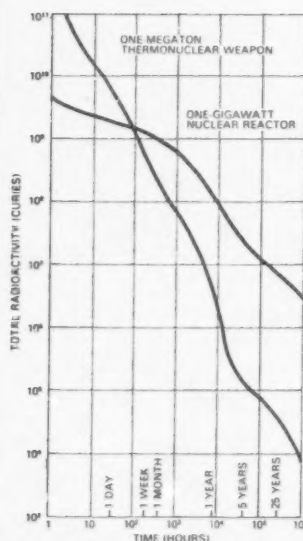


Figure 1. Decay of radioactivity released by the detonation of a nuclear weapon differs from the decay of the radioactivity released by a reactor accident because the two inventories of radioactive nuclei have different proportions of various isotopes. After an hour the radioactivity released by the detonation of a one-megaton thermonuclear weapon is 1000 times greater than the radioactivity that would escape in the worst conceivable peacetime reactor accident. On the other hand, the radioactivity from the reactor takes longer to decay. Source: S A Fetter and K Tsipis, *Scientific American* 244, 33 (1981).

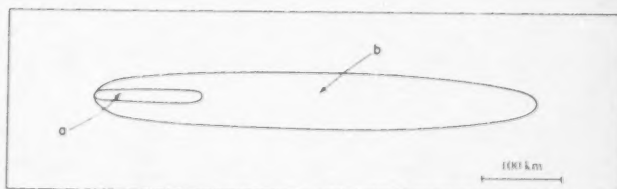


Figure 2. Contours of 100 rads (1 Gy) fallout dose in one year, starting one month after the detonation of a) a 1 Mt bomb, and b) a 1 Mt bomb on a 1 GW(e) nuclear reactor. Source: *Nuclear Radiation in Warfare* by Joseph Rotblat, SIPRI, 1981.

Table 3. Areas affected by detonation of nuclear weapons alone and nuclear power facilities.

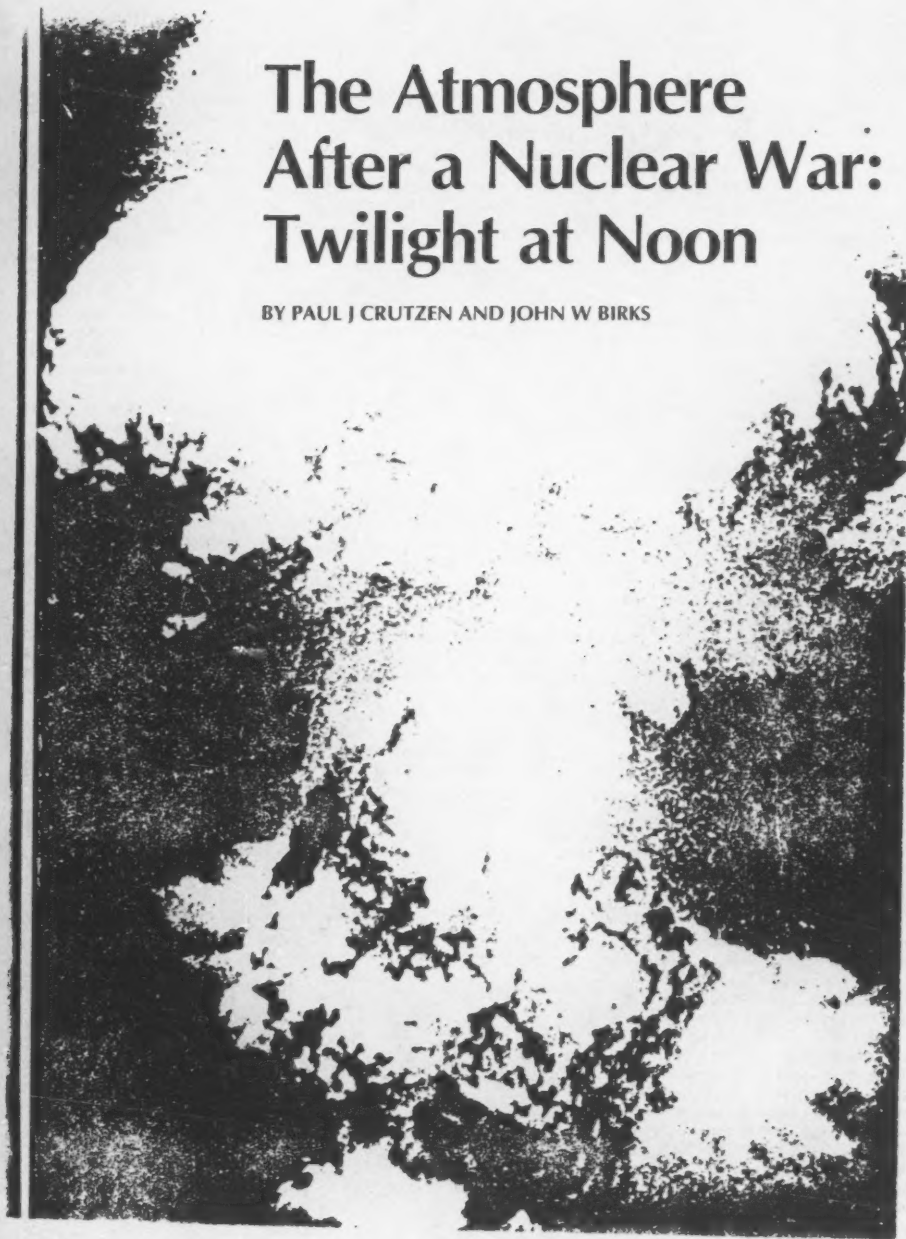
Dose* (rads)	Area (km ²) 1 Mt bomb	1 Mt bomb on 1 GW(e) reactor	1 Mt bomb on a storage tank
100	2 000	34 000	61 000
50	4 000	46 000	87 000
10	25 000	122 000	164 000

* Dose accumulated in one year starting one month after detonation.

Source: J Rotblat, *Nuclear Radiation in Warfare*, SIPRI, (Taylor and Francis, London, 1981). Dose converted to rads from Greys.

The Atmosphere After a Nuclear War: Twilight at Noon

BY PAUL J CRUTZEN AND JOHN W BIRKS



As a result of a nuclear war vast areas of forests will go up in smoke—corresponding at least to the combined land mass of Denmark, Norway and Sweden. In addition to the tremendous fires that will burn for weeks in cities and industrial centers, fires will also rage across croplands and it is likely that at least 1.5 billion tons of stored fossil fuels (mostly oil and gas) will be destroyed. The fires will produce a thick smoke layer that will drastically reduce the amount of sunlight reaching the earth's surface. This darkness would persist for many weeks, rendering any agricultural activity in the Northern Hemisphere virtually impossible if the war takes place during the growing season.

The immediate effects of a global nuclear war are so severe that any additional long-term effects might at first thought be regarded as insignificant in comparison. However, our investigation into the state of the atmosphere following a nuclear exchange suggests that other severely damaging effects to human life and the delicate ecosystems to which we belong will occur during the following weeks and months. Many of these effects have not been evaluated before.

Previous investigations of the atmospheric effects following a nuclear war have been concentrated primarily on the expected large depletions of ozone in the stratosphere (1,2). Reduction of the stratospheric ozone shield allows increased levels of harmful ultraviolet (uv) radiation to penetrate to the surface of the earth. Such ozone depletion results from the injection of oxides of nitrogen (NO_x) by large nuclear weapons having yields greater than one megaton. Should the nations having nuclear arsenals choose to use their large warheads in a nuclear war, then the earth's protective ozone layer would be much depleted, and the consequent adverse effects associated with the increased flux of ultraviolet radiation would occur. Our conclusions for such a scenario concur with those found in the 1975 report of the US National Academy of Sciences (1).

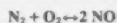
As assumed in Ambio's reference scenario, it is now believed that the most likely nuclear war is one in which few weapons having yields greater than 1 Mt are used, with preference given to the detonation of large numbers of smaller yield weapons. For such a nuclear war, very little NO_x would be injected above 15 km into the stratosphere by the nuclear bursts, and thus depletion of the ozone layer would not occur as a direct result of the explosions. Nonetheless, other profound effects on the atmosphere can be expected.

In discussing the state of the atmosphere following a nuclear exchange, we point especially to the effects of the many fires that would be ignited by the thousands of nuclear explosions in cities, forests, agricultural fields, and oil and gas fields. As a result of these fires, the loading of the atmosphere with strongly light absorbing particles in the submicron size range

(1 micron = 10^{-6} m) would increase so much that at noon solar radiation at the ground would be reduced by at least a factor of two and possibly a factor of greater than one hundred. In addition, fires inject large quantities of oxides of nitrogen and reactive hydrocarbons, the ingredients of photochemical smog. This creates the potential for photochemical smog throughout much of the Northern Hemisphere which may persist for several months after the particulate matter has been deposited on the ground. Such effects have been largely overlooked or not carefully examined in previous considerations of this problem. They are, therefore, considered in some detail in this study.

NUCLEAR WAR SCENARIOS

The explosion of nuclear weapons produces oxides of nitrogen by heating air to temperatures well above 2000 K. When the major constituents of the air—nitrogen and oxygen—are heated to high temperature, nitric oxide (NO) is formed. The equilibrium between N_2 , O_2 and NO is rapidly approached at the temperatures characteristic of the nuclear explosions:



As the temperature of the heated air falls, the reactions which maintain equilibrium become slow and NO cannot revert to the innocuous oxygen and nitrogen. Consequently, nuclear explosions produce NO in much the same way as it is formed as a pollutant in automobile and aircraft engines. A review of the mechanisms forming NO in nuclear explosions is provided in Appendix I. The oxides of nitrogen are important trace atmospheric constituents and play a very important role in atmospheric photochemistry. They are key constituents in the formation of photochemical smog in the troposphere, and the catalytic reaction cycle leading to ozone destruction is the principal means by which ozone concentrations are regulated in the stratosphere. In Appendix I it is estimated that there are 1×10^{12} molecules of NO formed for each megaton of explosion yield. As will be discussed later, large amounts of nitric oxide would also be formed by the many fires that would be started during a nuclear war.

With regard to direct NO_x formation in nuclear explosions, we consider two nuclear war scenarios. Scenario I is Ambio's reference scenario (3). In this scenario

Table 1. Distribution of NO_x produced by nuclear explosions for Scenario I ($\times 10^{12}$ molecules).

Alt. (km)	60°S-30°S	30°S-EQ	EQ-20°N	20°N-40°N	40°N-60°N	60°N-NP	Sum
30	-	-	-	0.7	-	-	0.7
29	-	-	-	0.7	1	-	1.7
28	-	-	-	2.3	1	-	3.3
27	-	-	-	2.3	3	-	5.3
26	-	-	-	2.3	3	-	5.3
25	-	-	-	2.3	3	-	5.3
24	-	-	-	3.7	3	-	6.7
23	-	-	-	3.7	5	-	8.7
22	-	-	-	3.7	5	-	8.7
21	-	-	-	3.7	5	-	8.7
20	-	-	-	2.1	5	-	7.1
19	-	-	-	2.1	2.8	-	4.9
18	-	0.3	1.1	0.1	2.8	-	4.3
17	-	1.1	3.5	10.4	0.2	-	15.2
16	0.7	3.5	10.8	30.7	24.5	-	70.2
15	2.3	8.9	27.5	30.7	72.9	-	142.3
14	2.3	8.9	27.5	116.8	72.9	1.1	229.5
13	3.7	13.0	39.7	247.7	121.5	3.5	429.1
12	8.5	12.1	36.7	225.1	276.6	3.5	562.5
11	16.6	6.6	20.4	329.4	533.5	11.9	916.4
10	14.6	0.5	1.5	327.3	470.2	26.4	840.5
9	24.4	-	-	183.2	775.8	25.0	1008.4
8	24.4	-	-	13.2	775.8	36.7	850.1
7	13.6	-	-	-	434.4	36.5	484.5
6	1.0	-	-	-	21.0	20.4	42.4
5	-	-	-	-	-	1.5	1.5
Sum	112.1	54.9	168.7	1544.2	3618.9	166.5	5665.3

bombs having a total yield of 5750 Mt are detonated. The latitudinal and vertical distributions of the 5.7×10^{25} molecules of nitric oxide produced in these explosions are determined by the weapon sizes and targets projected for this scenario. Since most of the weapons have yields less than 1 Mt, most of the NO_x is deposited in the troposphere, and the effect on the chemistry of the stratosphere is much less than if the bomb debris were deposited mainly in the stratosphere. The assumed NO input pattern for the Scenario I war is provided in Table 1.

The Scenario II war is similar to those used in previous studies by investigators using one-dimensional models and is included here mostly for historical reasons. This scenario considers a total yield of 10 000 Mt uniformly distributed between 20° and 60° in the Northern Hemisphere. The vertical distribution of NO is calculated assuming equal yields of 1-Mt and 10-Mt weapons, *ir* 5000 1-Mt weapons and 500 10-Mt weapons are detonated. For this scenario, equal quantities of NO_x are injected above and below 18 km, as seen in Table 2. Thus, the tropospheric effects for the Scenario II war are similar to those for the Scenario I war. However, the Scenario II war also results in an additional large perturbation of the stratospheric ozone layer.

FIRES

From an atmospheric point of view, the most serious effects of a nuclear war would most likely result from the many fires which would start in the war and could not

be extinguished because of nuclear contaminations and loss of water lines, fire equipment and expert personnel. The devastating effects of such fires in urban areas were indicated by Lewis (4). Here we show that the atmospheric effects would be especially dramatic. Several types of fires may rage. Besides the fires in urban and industrial centers, vast forest fires would start, extensive grasslands and agricultural land would burn, and it is likely that many natural gas and oil wells would be ruptured as a result of the nuclear explosions, releasing huge quantities of oil and natural gas, much of which would catch fire. To give an estimate of the possible effects, we will consider as a working hypothesis that 10^6 km^2 of forests will burn (this corresponds roughly to the combined area of Denmark, Norway and Sweden) and that breaks in gas and oil production wells will release gaseous effluents from the earth corresponding to the current rate of worldwide usage. In our opinion these are underestimates of the real extent of fires that would occur in a major nuclear war (see also Box 1).

Gaseous and Particulate Emissions from Forest Fires

In the US and especially in Canada and the USSR, vast forests are found close to important urban strategic centers, so that it may be expected that many wildfires would start burning during and after the nuclear exchange. Although it is hard to estimate how much forest area might burn, a total of 10^6 km^2 , spread around in the Northern Hemisphere, is probably an

underestimate, as it is only about 20 times larger than what is now annually consumed by wildfires (5). This amounts to 4 percent of the temperate and boreal forest lands, and is not larger than that of the urban areas combined (6). Furthermore, Ward *et al* (7) have pointed out that effective fire control and prevention programs have reduced the loss of forests in the US (exclusive of Alaska) from $1.8 \times 10^5 \text{ km}^2$ in the early 1930's to less than $1.6 \times 10^4 \text{ km}^2$ by the mid 1970's. The US Forest Service is quoted as estimating that a nuclear attack on the US of $\sim 1500 \text{ Mt}$ would burn a land area of $0.4\text{--}6 \times 10^6 \text{ km}^2$ in the US (8). All this information indicates that our assumption of 10^6 km^2 of forest area that could be consumed by fire is not an overestimate.

An area of 10^6 km^2 of forest contains on the average about $2.2 \times 10^{16} \text{ g}$ dry matter or about 10^{16} g of carbon phytomass (6) and about 10^{14} g of fixed nitrogen, not counting the material which is contained in soil organic matter. Typically, during forest wildfires about 25 percent of the available phytomass is burned (5), so that $2.5 \times 10^{15} \text{ g}$ of carbon would be released to the atmosphere. During wildfires about 75 kg of particulate matter is produced per ton of forest material burned or 450 kg of carbon (7), so that $4 \times 10^{14} \text{ g}$ of particulate matter is injected into the atmosphere by the forest fires. Independently, we can use the information by Ward *et al* (7) to estimate the global biomass and suspended particulate matter expected to be produced by wildfires which would be started by the nuclear war. According to these authors the forest area now burned annually in the US, excluding Alaska, is about $1.8 \times 10^4 \text{ km}^2$, which delivers $3.5 \times 10^{12} \text{ g}$ particulate matter to the atmosphere. Accordingly, a total area of 10^6 km^2 would inject $2 \times 10^{14} \text{ g}$ particulate matter into the atmosphere, which should come from $3 \times 10^{15} \text{ g}$ of burned forest material, or $1.3 \times 10^{15} \text{ g C}$. This is a factor of two less than the earlier derived estimate, so we will use a range of $1.3\text{--}2.5 \times 10^{15} \text{ g}$ of carbon as the global atmospheric gaseous release and $2\text{--}4 \times 10^{14} \text{ g}$ as particulate matter.

In forest fires most of the carbon is released as CO_2 to the atmosphere. The forest fire contribution to the atmospheric CO_2 content, which totals $7 \times 10^{17} \text{ g}$ of carbon, is rather insignificant. The repercussions of the forest fires are, however, much more important for the contribution of other gases to the atmosphere, *eg* carbon monoxide (CO). With a relative release rate ratio $\text{CO}:\text{CO}_2$ of about 15 percent (9), the production of CO would amount to $2\text{--}4 \times 10^{14} \text{ g C}$, which is roughly equal to or two times larger than the present atmospheric CO content (10). Within a short period of time, average concentrations of CO at midlatitudes in the Northern Hemisphere would increase by up to a factor of four, and much larger CO increases may be expected on the continents, especially

Table 2. Distribution of NO_x produced by nuclear explosions for Scenario II ($\times 10^{25}$ molecules).

Alt. (km)	$20^\circ\text{N--}40^\circ\text{N}$	$40^\circ\text{N--}60^\circ\text{N}$	Sum
31	62	62	124
30	62	62	124
29	188	188	376
28	188	188	376
27	188	188	376
26	188	188	376
25	312	312	624
24	312	312	624
23	312	312	624
22	312	312	624
21	175	175	350
20	175	175	350
19	80	80	160
18	54	54	108
17	80	80	160
16	125	125	250
15	375	375	750
14	375	375	750
13	625	625	1250
12	625	625	1250
11	350	350	700
10	25	25	50
Sum	5 000	5 000	10 000

BOX 1.

The attenuations of sunlight at great distances from forest fires have been documented for many years. Phenomena such as "dark days", "dry fog", "Indian summer" and "colored rain" are now attributed to smoke produced by fires in forests, prairies and peat bogs. The great forest fires during October 13-17, 1918 in Minnesota and adjacent sections of Wisconsin produced smoke that had strong optical effects and could even be smelled as far away as the eastern US coast. A report from Cincinnati, Ohio is particularly descriptive (H Lyman, Reference 17): "At 3 PM the smoke and haze became denser, but the sun's light and its disk could be seen until 3:35 PM, at which time the sun was entirely obscured. Objects at this time could not be seen at a distance of 300 feet." More than 100

forest fires in northwestern Alberta and northeastern British Columbia resulted in the "Great Smoke Pall" of September 24-30, 1950 with press reports carrying accounts of smoke being observed as far away as England, France, Portugal, Denmark and Sweden (H Wexler, Reference 17). Most of Canada and the eastern one-third of the continental US were particularly affected. In the eastern US the smoke was confined to the altitude range of about 2.5-4.5 km, so that there was no reduced visibility at the ground. However, the sun was so obscured that it was visible to the naked eye without discomfort and had what was typically described as a violet or lavender color. Measurements in Washington, DC indicated that the solar intensity was reduced by a factor of two on September 25-26 in the absence of clouds.

in regions downwind (generally east of the fires). Accompanying those emissions there will also be significant inputs of tens of Teragrams (1 Teragram = $1 \text{ Tg} = 10^{12} \text{ g}$) of reactive hydrocarbons to the atmosphere, mostly ethylene (C_2H_4) and propylene (C_3H_6), which are important ingredients in urban, photochemical smog formation. More important, phytomass consists roughly of about 1 percent fixed nitrogen, which is mainly contained in the smaller-sized material such as leaves, bark, twigs and small branches, which are preferentially burned during fires. As a rough estimate, because of the forest fires we may expect an input of 15-30 Tg of nitrogen into the atmosphere (7). Such an emission of NO would be larger than the production in the nuclear fireballs and comparable to the entire annual input of NO_x by industrial processes. Considering the critical role of NO in the production of tropospheric ozone, it is conceivable that a large accumulation of ozone in the troposphere, leading to global photochemical smog conditions, may take place. An increase of ozone due to photochemical processes in forest fire plumes has indeed been observed by several investigators (11, 12).

Particulate Matter from Forest Fires and Screening of Sunlight

The total production of $2-4 \times 10^{14} \text{ g}$ of particulate matter from the burning of 10^6 km^2 of forests is comparable on a volume basis to the total global production of particulate matter with diameter less than 3 microns (μm) over an entire year (or 200-400 million tons, 13). The physical and chemical nature of this material has been reviewed (14).

The bulk of the mass (>90 percent) of the particulate matter from forest fires consists of particles with diameters of less than $1 \mu\text{m}$ and a maximum particle number density at a diameter of $0.1 \mu\text{m}$. The material has a very high organic matter content (40-75 percent) and much of it is

formed from gaseous organic precursors. Its composition is on the average: 55 percent tar, 25 percent soot and 20 percent ash. These particles strongly absorb sunlight and infrared radiation. The light extinction coefficient, $b_v(\text{m})$, is related to the smoke density, $d(\text{g/m}^3)$, by the relationship $b_v = ad$, where a is approximately $4-9 \text{ m}^2/\text{g}$ (14, 15). With most smoke particles in the submicron size range, their average residence time in the atmosphere is about 5-10 days (13). If we assume that the forest fires will last for two months (16), a spread of $2-4 \times 10^{14} \text{ g}$ of aerosol over half of the Northern Hemisphere will cause an average particle loading such that the integrated vertical column of particles is equal to $0.1-0.5 \text{ g/m}^2$. As a result, the average sunlight penetration to the ground will be reduced by a factor between 2 and 150 at noontime in the summer. This would imply that much of the Northern Hemisphere would be darkened in the daytime for an extended period of time following the nuclear exchange. The large-scale atmospheric effects of massive forest fires have been documented in a number of papers (16, 17). Big forest fires in arctic regions are commonly accompanied by huge fires in peat bogs, which may burn over two meters in depth without any possibility of being extinguished (16). The production of aerosol by such fires has not been included in the above estimates.

Gas, Oil and Urban Fires

In addition to the above mentioned fires there are also the effects of fires in cities and industrial centers, where huge quantities of combustible materials and chemicals are stored. As an example, if the European 95-day energy stockpile is roughly representative for the world (18), about $1.5 \times 10^{15} \text{ g}$ C fossil fuel (around 1.5 thousand million tons) is stored globally. Much of this would be destroyed in the event of a nuclear war. Therefore, if the relative emission yields of particulate matter by oil and gas fires are about equal to

those of forest fires, similar rates of production of atmospheric aerosol would result. Although it may be enormously important, in this study we will not consider the global environmental impacts of the burning and release of chemicals from urban and industrial fires, as we do not yet have enough information available to discuss this matter in a quantitative manner.

Even more serious atmospheric consequences are possible, due to the many fires which would start when oil and gas production wells are destroyed, being among the principal targets included in the main scenario provided for this study (5). Large quantities of oil and gas which are now contained under high pressure would then flow up to the earth's surface or escape into the atmosphere, accompanied by huge fires. Of course, it is not possible for the nuclear powers to target all of the more than 600 000 gas and oil wells of the world. However, certain regions of the world where production is both large and concentrated in small areas are likely to be prime targets in a nuclear war. Furthermore, the blowout of a natural gas well results in the release of gas at a much greater rate than is allowed when under control and in a production network. For example, one of the more famous blowouts, "The Devil's Cigarette Lighter", occurred at Gassi Toul in the Sahara. This well released $15 \times 10^6 \text{ m}^3$ of gas per day until the 200-meter high flame was finally extinguished by explosives and the well capped (19). Fewer than 300 such blowouts would be required to release natural gas (partly burned) to the atmosphere at a rate equal to present consumption. Descriptions of other blowouts such as the Ekofisk Bravo oil platform in the North Sea (20), a sour gas well (27 percent H_2S) in the province of Alberta, Canada (21) and the Ixtoc I oil well in the Gulf of Mexico (22) may be found in the literature.

As an example of how very few weapons could be used to release large quantities of natural gas, consider the gas fields of the

Netherlands. The 1980 production of 7.9×10^{10} m³ of natural gas in Groningen amounted to 38 percent of that for all of Western Europe and 5 percent of that for the entire world (19). Most of the gas production in the Netherlands is concentrated in a field of about 700 km² area. It seems likely that a 300-kt nuclear burst would uncup every gas well within a radius of 1 km either by melting the metal pipes and valves, by snapping the pipes off at the ground by the shock wave, or by breaking the well casings via shock waves propagated in the earth. This is in consideration of the following facts (23): 1) the fireball radius is 0.9 km, 2) for a surface burst the crater formed is approximately 50 m deep and 270 m in diameter, 3) the maximum overpressure at 1 km is 3.1 atmospheres (atm), 4) the maximum dynamic pressure at 1 km is 3.4 atm, and 5) the maximum wind speed at 1 km is 1700 km/h. Considering then that a 300-kt bomb has a cross-section of greater than 3 km² for opening gas wells, fewer than 230 such weapons are required to cover the entire 700 km² Groningen field of the Netherlands. This amounts to less than 69 Mt of the 5750 Mt available for the Scenario 1 nuclear war.

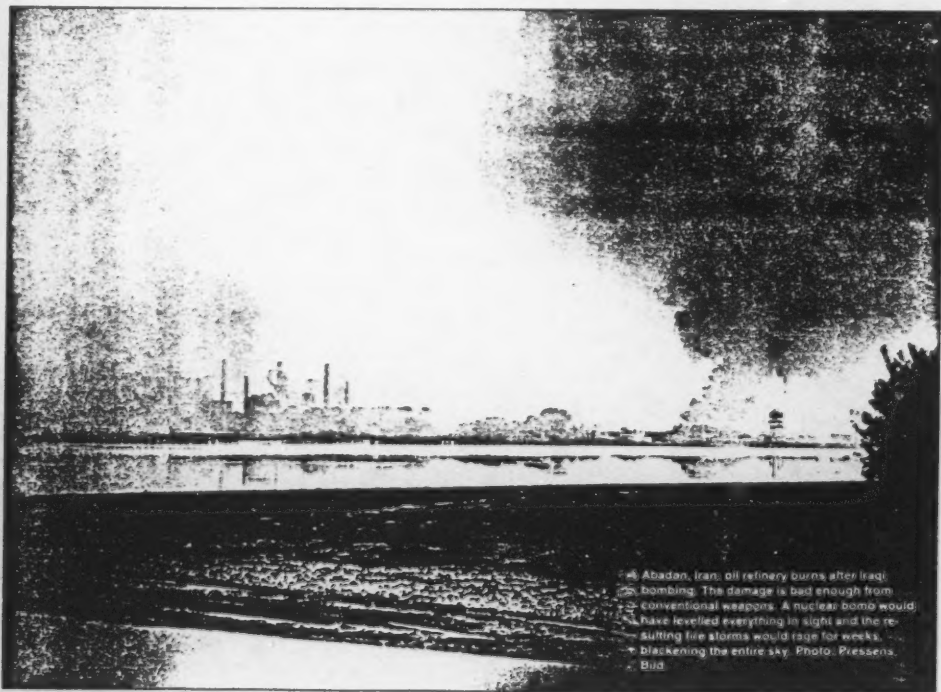
Offshore oil and gas platforms might also be targets of a nuclear war. For example, in 1980 the United Kingdom and Norway produced 2.1×10^6 barrels of oil per day from a total of 390 wells (about 40 platforms) in the North Sea (19). Considering that a 100-kt weapon would be more than sufficient to destroy an offshore platform, only 4 Mt of explosive yield need be used to uncup these wells, which produce 3.5 percent of the world's petroleum.

One can point out many other regions of the world where gas and oil production is particularly concentrated. Production in the US is considerably more dispersed than in other countries, however. For comparison, in 1980 the US produced an average of 8.6×10^6 barrels of oil per day from about 530 000 wells whereas the USSR production was 12.1×10^6 barrels per day from only 80 000 wells (19). The oil and gas fields of the Soviet Union, particularly the oil producing Volga-Ural region and the gas and oil fields of the Ob region, are highly localized and particularly vulnerable to nuclear attack.

Much of the gas and oil released as a result of nuclear attacks will burn. This is another source of copious amounts of particulate matter in the atmosphere. However,

it is also likely that a fraction of the gas would escape unburned to the atmosphere where it would be gradually broken down by photochemical reactions. Much of the escaping oil may likewise burn, but an appreciable portion of it may volatilize as in the Ixtoc 1 blowout in the Gulf of Mexico, which resulted in the world's largest oilspill. In this case it is estimated that only 1 percent of the oil burned, while 50–70 percent evaporated (22). We next consider the influence of these emissions on the gaseous composition of the atmosphere.

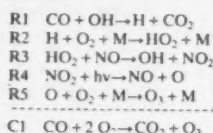
Natural gas consists usually of a mixture of 80–95 percent (by volume) methane (CH₄) and the remaining 5–20 percent heavier hydrocarbons, mainly ethane (C₂H₆) and propane (C₃H₈), and varying amounts of carbon dioxide and nitrogen. Current global consumption of natural gas amounts to about 10^{15} g of carbon per year, which is 20 percent of the total fossil fuel consumption rate (24). The current atmospheric content of ethane is equal to about 6×10^{12} g of carbon, based on observations indicating amounts of 1 ppbv (1 ppbv = 10^{-9} by volume) in the Southern and 2 ppbv in the Northern Hemisphere (25). Consequently the rapid release of C₂H₆ by blow-outs during a nuclear war



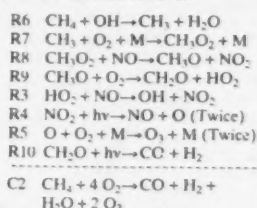
Abadan, Iran, oil refinery burns after Iraqi bombing. The damage is bad enough from conventional weapons. A nuclear bomb would have levelled everything in sight and the resulting fire storms would rage for weeks, blackening the entire sky. Photo: Pressens. Bid.

BOX 2

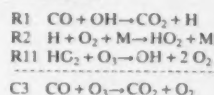
Reaction Cycle C1. In the presence of sufficient NO the oxidation of CO to CO₂ results in the formation of ozone as follows:



Reaction Cycle C2. The oxidation of methane in the atmosphere leads to ozone formation as follows:



Reaction Cycle C3. In the absence of sufficient NO in the atmosphere the oxidation of CO leads to ozone destruction as follows:



can increase by many-fold the atmospheric concentrations of this gas, which has an atmospheric residence time of about two months. Similar conclusions can be drawn with regard to the higher hydrocarbons. Although relative increases of methane in the atmosphere will take place at a relatively slower pace—as its present atmospheric abundance is much larger, 3×10^{15} g of carbon—even here the atmospheric concentrations may multiply if a sufficiently large percentage of the gas wells are being destroyed. Once destroyed, it seems unlikely that quick repair can be possible in a chaotic world in which little expert personnel and equipment will be available, while the fields will furthermore be heavily contaminated with radioactivity.

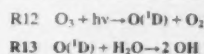
Of course it is impossible to guess how many oil and gas well destructions would result from a nuclear war, how much gas will burn and how much will escape unburned to the atmosphere. As an example to indicate the atmospheric effects, let us assume that quantities of oil and gas will continue to burn corresponding to present usage rates, with 25 percent of the present production gas escaping unburned into the atmosphere. We do not know whether the latter assumption is realistic. If not, the chosen conditions may represent a gross underestimate of the atmospheric emissions which could take place during and after a nuclear war. This is, of course, especially the case when the world's oil and gas production fields are targeted as foreseen in the main scenario of this study. We simulate NO_x emissions from oil and gas field fires with those provided by current industrial rates. This adds 20 Tg of nitrogen to the NO_x source from forest fires.

TROPOSPHERIC PHOTOCHEMISTRY

For the Scenario I nuclear war most of the bomb cloud remains in the troposphere. The sudden input of a large quantity of nitric oxide of 5.7×10^{15} molecules (12 Tg

nitrogen) by nuclear explosions and the more gradual input of NO_x from forest fires and gas and oil well fires, mainly in the Northern Hemisphere, will cause important changes in the course of the photochemical reactions taking place. Of course, these reactions should occur only in regions where sufficient sunlight would still penetrate. Alternatively, these reactions begin to occur after an appreciable fraction of the aerosol loading of the atmosphere has diminished because of removal of the particulate matter by rain or dry deposition. The following discussion is, therefore, mainly aimed at illustrating the sort of photochemical effects that may take place. The presence of NO in the troposphere favors chemical processes leading to the production of ozone, eg during the oxidation of carbon monoxide (CO) and methane (CH₄), which are present at part per million levels as normal constituents of the troposphere. The production of ozone in these cases takes place with OH, HO₂, NO and NO₂ as catalysts via the cycles of reaction C1 and C2 shown in Box 2. Under present non-war conditions, it appears that a large fraction of the troposphere does not contain enough NO for ozone production to take place. For such conditions the oxidation of CO occurs instead via the reaction cycle C3 of Box 2. In contrast to reaction cycle C1, cycle C3 leads to ozone destruction. From a comparison of reaction cycles C1 and C3, it follows that ozone production takes place as long as the atmospheric concentration of NO exceeds 1/4000 that of O₃, which is the ratio of rate coefficients for the reactions R11 and R3 (26, 27). If enough NO were present everywhere in the troposphere for all atmospheric oxidation of CO and CH₄ to occur via reaction cycles C1 and C2, the globally averaged, vertical column integrated photochemical production of ozone in the troposphere would be much larger ($\sim 5 \times 10^{11}$ molecules/cm²/s) than can be balanced by destruction at the earth's sur-

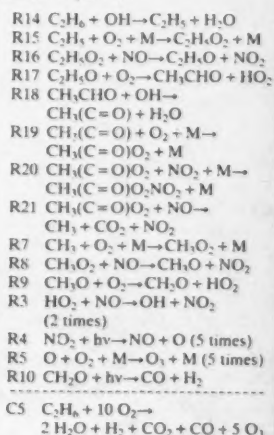
face ($\sim 6 \times 10^{11}$ molecules/cm²/s) and by photochemical removal via the reactions



which is estimated at 8×10^{11} molecules/cm²/s (28, 29). Reactions R12 and R13 constitute the main pathway for the production of hydroxyl radicals (OH), which initiate many oxidation processes in the atmosphere.

BOX 3

Reaction Cycle C4. Atmospheric oxidation of ethane forms ozone as follows. The carbon monoxide (CO) produced may also be oxidized to form additional ozone via cycle C1.



The photochemistry of the ethane and higher hydrocarbon oxidation in the atmosphere follows similar reaction paths as for methane, although reactions occur faster because of the higher reactivity of these molecules (27, 30). In the case of ethane, there can be a net production of five ozone molecules per ethane molecule consumed, if sufficient NO is present in the atmosphere. The cycle of reactions, cycle C4, that produces ozone from ethane is shown in Box 3. The compound peroxyacetylnitrate, $\text{CH}_3(\text{C}=\text{O})\text{O}_2\text{NO}_2$, which appears in C4 is a strong phytotoxicant and air pollutant, better known by the acronym PAN (31). The compound, CH_2O , is formaldehyde and CH_3CHO is acetaldehyde.

Few observations of NO in the background atmosphere have been made, mainly due to the extreme difficulties which are involved in its measurement at low concentrations (32, 33). The hypothesis that ozone production may take place only in a relatively small fraction of the troposphere is in accordance with present estimations of the sources and sinks of tropospheric NO_x (34). According to this compilation, the tropospheric sources of NO_x are dominated by industrial activities. This could imply that the current concentrations of tropospheric ozone in the Northern Hemisphere are substantially larger than those which prevailed during pre-industrial times.

We have modeled the atmospheric photochemistry following a Scenario I nuclear war under the illustrative assumptions listed above. A description of the computer model used in this work is provided in Appendix II. The mixing ratios of ozone in the present atmosphere as calculated by the unperturbed model for August 1 are provided in Figure 1, and these are in good agreement with the observations (35). The calculated ozone concentrations on August 1, 50 days after the start of the war, are shown in Figure 2. We notice the possibility of severe world-wide smog conditions resulting in high concentrations of ozone. With time, at midlatitudes in the Northern Hemisphere there may be large accumulations of ethane (50–100 ppbv) and PAN (1–10 ppbv).

EFFECTS OF TROPOSPHERIC COMPOSITION CHANGES

For Ambio's Scenario I type of war the most significant effects in the atmosphere will occur as a result of the wide variety of large fires, which affect especially military, urban and industrial centers, agricultural fields, oil and gas production areas, and forests. In the preceding section, we have considered a scenario of events which, in our opinion, represents probably the minimum of what may occur: wildfires in 10^6 km^2 of forests, and the burning and escape of oil and natural gas at rates comparable to present industrial usage. The estimated atmospheric effects are very large. The

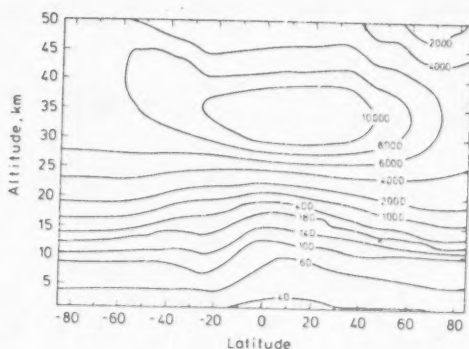
fires would create sufficient quantities of airborne particulate matter in the atmosphere to screen out a large fraction of the solar radiation for many weeks, strongly reducing or even eliminating the possibility of growing agricultural crops over large areas of the Northern Hemisphere. Dark aerosol deposits on the vegetation would likewise severely limit plant productivity. In addition, if the war should start during the summer months, as envisaged in the war scenario of this study, much cropland would be destroyed directly by fast-moving fires. Also of special concern are the heavy deposits of air pollutants from the atmosphere which would take place in the months during and following the war. If an appreciable fraction of the NO_x formed in the nuclear explosions and in the resulting fires were to be deposited in rain, the rainwater would be highly acidic with an average pH of less than 4.

If the production of aerosol by fires is large enough to cause reductions in the penetration of sunlight to ground level by a factor of a hundred, which would be quite possible in the event of an all-out nuclear war, most of the phytoplankton and herbivorous zooplankton in more than half of the Northern Hemisphere oceans would die (36). This effect is due to the fast consumption rate of phytoplankton by zooplankton in the oceans. The effects of a darkening of such a magnitude have been discussed recently in connection with the probable occurrence of such an event as a result of the impact of a large extraterres-

trial body with the earth (37). This event is believed by many to have caused the widespread and massive extinctions which took place at the Cretaceous-Tertiary boundary about 65 million years ago.

For several weeks following the war the physical properties of the Northern Hemisphere troposphere would be fundamentally altered, with most solar energy input being absorbed in the atmosphere instead of at the ground. The normal dynamic and temperature structure of the atmosphere would therefore change considerably over a large fraction of the Northern Hemisphere, which will probably lead to important changes in land surface temperatures and wind systems. The thick, dark aerosol layer would likely give rise to very stable conditions in the troposphere (below 10 km) which would restrict the removal of the many fire-produced and unhealthy pollutants from the atmosphere. Furthermore, fires also produce as many as 6×10^{10} cloud condensation nuclei per gram of wood consumed. The effect of many condensation nuclei is to narrow the cloud droplet size distribution and suppress formation of rain droplets by coalescence, probably leading to a decrease in the efficiency with which clouds can produce rain (38). The influence of large-scale vegetation fires on weather has been recognized by researchers for many years (eg 39). After the settling of most of the particulate matter, ozone concentrations over much of the Northern Hemisphere could approach 160 ppbv for some months fol-

Figure 1. Ozone mixing ratios (ppbv, $1 \text{ ppbv} = 10^{-9}$) in the present atmosphere as calculated by the 2-D model for August 1.



lowing the war. With time, substantial increases in other pollutants such as PAN to several ppbv may also occur. These species are important air pollutants which are normally present in the atmosphere at much lower concentrations (~30 ppbv for ozone and less than 0.1 ppbv for PAN) (33, 40, 41).

The effects of ozone on public health and plant growth have been studied for several decades, especially in the US in connection with the Los Angeles basin photochemical smog problem. The effects on agricultural plants may be particularly severe. A major EPA report (31), listed several examples of decreases in yields of agricultural crops. For instance: "A 30 percent reduction in the yield of wheat occurred when wheat at anthesis [blooming] was exposed to ozone at 200 ppbv, 4 hours a day for 7 days... Chronic exposures to ozone at 50-150 ppbv for 4-6 hours a day reduced yields in soybeans and corn grown under field conditions. The threshold for measurable effects for ozone appear to be between 50 and 100 ppbv for sensitive plant cultivars... An ozone concentration of 50 to 70 ppbv for 4 to 6 hours per day for 15 to 133 days can significantly inhibit plant growth and yield of certain species."

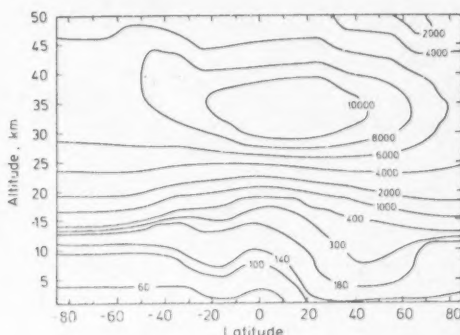
As a result of the nuclear holocaust we have indicated the possibility of an increase of average ground level ozone concentration to 160 ppbv with higher values to be expected in areas in the wake of the mix of forest and gas and oil well fires assumed in this study. It follows, therefore, that agricultural crops may become subjected to severe photochemical pollutant stress in addition to the even greater damaging effects due to the large load of aerosol particles in the atmosphere.

We conclude, therefore, that the atmospheric effects of the many fires started by the nuclear war would be severe. For the war scenario adopted in this study, it appears highly unlikely that agricultural crop yield would be sufficient to feed more than a small part of the remaining population, so many of the survivors of the initial effects of the nuclear war would probably die of starvation during the first post-war years. This analysis does not address the additional complicating adverse effects of radioactivity or synergism due to concomitant use of chemical and biological warfare weapons.

The described impacts will be different if a nuclear war starts in the winter months. Forest areas burned may be half as large (7), photochemical reactions would be slower because of less solar radiation and lower temperatures. However, in winter-time, because of the low sun, the darkness caused by the fire-produced aerosol would be much worse.

In this work little discussion could be devoted to the health effects of fire-produced pollutants. They too, no doubt, will be more serious in winter than in summer.

Figure 2. Ozone mixing ratios (ppbv) on August 1, 50 days after the beginning of the Scenario I nuclear war. Inputs from forest fires and oil and gas well fires as described in the text.

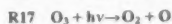
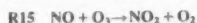


STRATOSPHERIC OZONE DEPLETION

In the stratosphere, molecular oxygen, O_2 , absorbs solar radiation of wavelengths shorter than 242 nm and dissociates into two oxygen atoms. These oxygen atoms combine with two oxygen molecules to form two ozone molecules as follows:



This formation mechanism is quite different from that described previously for the troposphere and summarized in cycles C1 and C2 of Box 2. Whereas oxides of nitrogen promote ozone formation in the troposphere, in the stratosphere, where the chemical composition and light spectrum are quite different, the effect of oxides of nitrogen is to catalyze ozone destruction via the reactions:



It is now recognized that this cycle is the principal means by which ozone is limited in the natural stratosphere (42). Also, whereas ozone is an undesirable pollutant in the troposphere, in the stratosphere ozone performs the necessary function of shielding the earth's surface from biologically damaging ultraviolet radiation.

Our model does not predict significant stratospheric ozone depletion for Ambio's reference Scenario I since as seen in Table 1, very little NO_x is deposited in the stratosphere for this scenario. However, for Scenario II (based on previous studies)—which considers the detonation of numerous weapons of large yield—the model predicts very large depletions. For this scenario the quantity of NO_x in the stratosphere of the Northern Hemisphere is increased by a factor of approximately twenty above the natural level (21). The resulting large ozone depletions would begin in the Northern Hemisphere and eventually spread to the Southern Hemisphere. For purposes of illustration, the Scenario II nuclear war begins on June 11. The resulting ozone depletions on November 1 of the same year are shown in Figure 3. These large ozone depletions are consistent with the one-dimensional model results of Whitten, Borucki and Turco (2) and with the result of Chang as reported by the US National Academy of Sciences (1).

Whitten *et al* (2) considered total bomb yields in the range of 5000-10 000 Mt. They distributed the weapon yields either equally between 1-Mt and 5-Mt weapons or equally between 1-Mt and 3-Mt weapons. They also considered that the NO_x was either uniformly distributed throughout the Northern Hemisphere or spread uniformly between 30° and 70° N. Maximum depletion of the ozone column occurred two to three months following the NO_x injection and ranged from 35-70

percent. The 35 percent depletion occurred for the 5000 Mt total yield distributed equally between 1-Mt and 3-Mt bombs and spread uniformly over the entire Northern Hemisphere. The maximum of 70 percent depletion occurred for a total bomb yield of 10 000 Mt distributed equally between 1-Mt and 5-Mt explosions and confined to the region 30°–70° N. The time constant (e-folding time) for ozone recovery was approximately three years.

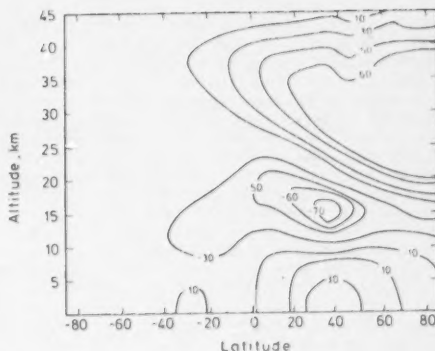
The NAS report (1) reaches similar conclusions. A 10 000 Mt war, confined to the Northern Hemisphere, is projected to result in a 30–70 percent ozone column reduction in the Northern Hemisphere and a 20–40 percent reduction in the Southern Hemisphere. Again, the characteristic recovery time was found to be approximately three years. Within ten years the ozone column depletions were estimated to have decreased to 1–2 percent.

Our two-dimensional model predicts a rather uniform 65 percent depletion of the ozone column spread from 45° N to the North Pole by the 50th day following the war. The depletions become less toward the equator and beyond, being 57, 42, 26, 12 and 1 percent at 35° N, 25° N, 15° N, 5° N and 5° S, respectively. As time progresses, the ozone depletions become less in the Northern Hemisphere, but NO_x is transported to the Southern Hemisphere and causes significant depletion there. Two years following the war in the Northern Hemisphere the ozone column depletions vary uniformly from 15 percent at 5° N to 56 percent at 85° N, with a 39 percent depletion of the ozone column at 45° N. At the same time ozone column depletions range from 12 percent at 5° S to 18 percent at 85° S in the Southern Hemisphere.

An important uncertainty in the model calculations for the stratosphere stems from the perturbations in the heating rates that accompany the large ozone depletions. Reduction of ozone causes a cooling of the stratosphere. By absorbing ultraviolet sunlight, ozone heats the atmosphere and causes the temperature inversion that is responsible for the high degree of resistance to vertical mixing. To a large extent the NO_x is partitioned into NO_2 in the stratosphere, and the absorption of solar radiation by this species also heats the stratosphere. We find that the net effect at midlatitudes in the perturbed stratosphere is heating below about 22 km and cooling above. The net heating below 22 km is due both to greater penetration of solar uv as a result of the reduced ozone column and the added heating in this region due to NO_2 . This will undoubtedly affect the dynamics of the stratosphere and the temperature profile in the stratosphere in complex ways which we cannot predict. We can be confident, however, that the perturbation in the ozone column would be quite large for a Scenario II nuclear war.

Finally, we may point out that there is a

Figure 3. Atmospheric ozone depletion (%) on August 1 of the same year as the Scenario II nuclear war. Negative values indicate ozone increases and show the opposite effects of NO_x injections on ozone in the upper and lower regions of the atmosphere.



possibility that even a nuclear war according to Scenario I, in which most NO_x is deposited in the troposphere, may cause ozone depletions in the stratosphere, if the hot fires in the oil and gas production regions become so powerful that the fire plumes penetrate into the stratosphere. Another means of upward transport may occur when the heavy, dark aerosol layer, initially located in the troposphere, is heated by solar radiation and starts to set up convection and wind systems which will transport an appreciable fraction of the fire effluents into the stratosphere. These speculative thoughts may be pursued further with currently available general circulation models of the atmosphere.

Past Nuclear Weapons Tests

In light of this discussion, one might naturally ask whether past nuclear weapon testing in the atmosphere resulted in significant ozone depletion. This topic has been the subject of considerable debate (43–52). That nuclear explosions produce copious quantities of nitric oxide and that multi-megaton bursts deposit this NO in the stratosphere was first recognized by Foley and Ruderman (44). The problem was presented as a possible test of whether NO_x from SST airplane exhaust would actually damage the ozone layer as suggested by Johnston (53) and Crutzen (54). The approximately 300 Mt of total bomb yield in a number of atmospheric tests by the US and USSR in 1961 and 1962 introduced about 3×10^{14} additional molecules of NO to the stratosphere. Using a one-dimensional model, Chang, Duewer and Wuebbles (49) estimated that nuclear weapon testing resulted in a maximum ozone depletion in the Northern Hemisphere of about 4 percent in 1963. Analysis of the ground ozone observational data for the Northern Hemisphere by Johnston, Whitten and Birks (45) revealed a de-

crease of 2.2 percent for 1960–1962 followed by an increase of 4.4 percent in 1963–1970. These data are consistent with the magnitude of ozone depletion expected, but by no means is a cause-and-effect relationship established. Angell and Korshover attribute these ozone column changes to meteorological factors (47, 48). The ozone increase began before most of the large weapons had been detonated and persisted for too long a period to be totally attributed to recovery from bomb-induced ozone depletion. Considering the large scatter in ozone measurements and our lack of understanding of all of the natural causes of ozone fluctuations, we cannot draw definite conclusions based on ground observations of ozone following the nuclear weapons tests of the late 1950's and early 1960's.

Solar Proton Events

From the previous discussion it is clear that we have no direct experimental evidence for stratospheric ozone depletion as a result of nuclear explosions. However, at least for altitudes above 30 km the sudden input of significant amounts of NO_x has clearly been shown to lead to large ozone destructions. In August 1972 a major solar proton event deposited large amounts of nitrogen oxides in the stratosphere, leading to ozone depletions poleward of about 60° N. The estimated ozone depletions calculated with a photochemical model were confirmed by satellite observations of stratospheric ozone (55).

EFFECTS OF INCREASED UV-B RADIATION

Ozone in the stratosphere serves as a protective shield against the harmful effects of solar radiation in the wavelength region 240–320 nm (10^{-9} meter). The flux of radiation in the wavelength region 290–320 nm ("uv-B" radiation) is particularly

sensitive to very small changes in the ozone column (1). This biologically active radiation is also absorbed by the proteins and nucleic acids within living cells, resulting in a large variety of photochemical reactions and consequent cell damage (56-58).

The expected adverse effects of increased levels of uv-B radiation include increased incidence of skin cancer in fair-skinned races, decreased crop yields and a variety of stresses on terrestrial and aquatic ecosystems. Such effects have been considered in the past in connection with possible reduction of the ozone shield by the operation of fleets of SST airplanes (59) and by the continued release of chlorofluoromethanes used as refrigerants and as propellants in aerosol spray cans (60). The information available is insufficient to allow quantification of most of these effects. Epidemiological data were used in the NAS study (1) to estimate that a 50 percent ozone shield reduction lasting three years would lead to an increase of skin carcinoma and melanoma of 3 percent to 30 percent at midlatitudes, with a geometric mean of about 10 percent, that will persist for 40 years. This may be compared with the estimate made in the same study that during the first generation a 10 000 Mt war would increase the spontaneous cancer death rate by about 2 percent as a result of exposure to low levels of ionizing radiation from radioactive fallout.

Effects of increased uv-B radiation on food crops are extremely difficult to predict. The sensitivity of plants to supplemented uv-B has been found to be highly variable from one species to another. For example, whereas peas and onions are sensitive, more important food crops such as soybeans and corn appear to have a higher tolerance (1). Possible climatic changes following a nuclear war further complicate the picture for food crops. Crops are particularly sensitive to temperature, length of growing season and amount of precipitation. The coupling of significant changes in one or all of these factors with a change in the spectrum and intensity of light reaching the earth's surface could be particularly detrimental.

Reduction in stratospheric ozone and the concomitant increase in uv-B radiation would also stress natural ecosystems. As in agriculture, individual species of plants and animals differ considerably in their sensitivities to uv-B radiation. However, in natural ecosystems a direct effect on only one species may be propagated to a large number of species because of complex interdependencies. For example, the food chain of the oceans is based on photosynthesis by phytoplankton, and these microscopic, green plants have been demonstrated to be quite sensitive to uv radiation (60). It was estimated from uv-B irradiation experiments that a 16 percent ozone reduction (the degree of ozone depletion projected by the NAS study for continued release of chlorofluoromethanes) could

kill up to 50 percent of the anchovies in the top 10 meters of the clearest ocean water or else require them to substantially deepen their usual water depth (60, 61). Avoidance could provide protection for many animals, but it is thought that few species can sense uv-B light.

The "effective" increases in uv-B radiation may be determined by integrating the product of the uv-B radiation flux and the appropriate "action spectrum" over wavelength. We have computed these integrals using the action spectrum for erythema (sunburn). This action spectrum is very similar to the absorption spectrum of DNA, as are most uv-B action spectra, and thus the results apply rather generally to cell damage of all types (62). The relative increases in effective uv-B radiation are shown in Figure 4 for several latitudes as a function of time following the nuclear war. As noted earlier, the uv-B increases are extremely large and persist for several years. The Scenario II nuclear war initially

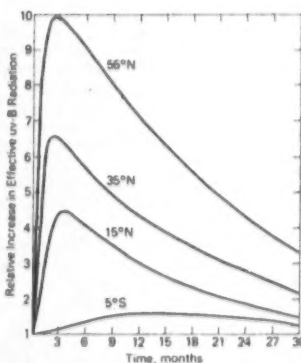


Figure 4. Relative increases in effective uv-B radiation based on the erythema action spectrum for the Scenario II nuclear war.

would result in increases in uv-B radiation by a factor greater than 5 throughout most of the Northern Hemisphere and greater than 10 between 55°N and the North Pole. These large increases in uv-B radiation are expected to persist long after the attenuation of light by atmospheric aerosol produced by the nuclear blasts and by the many fires is no longer significant. By comparison, the projected increase in effective uv-B radiation for continued release of chlorofluoromethanes at 1977 levels is 44 percent (60).

LONG-TERM EFFECTS

Regarding possible climatic effects, little can be said with confidence. The increase in tropospheric ozone, methane and possibly other pollutant gases may lead to increased temperatures at the earth's surface (63, 64), while the dark aerosol produced by the fires will change the heat and radiative balance and dynamics of the earth and the atmosphere for awhile. Longer lasting effects may be caused by the changes in the reflective properties of the land surfaces because of many fires. In a recent study Hansen *et al.* (65) have been able to trace observed mean global temperatures over the past 100 years with a simple climate model by introducing changes in the atmospheric CO₂ content, volcanic activity and solar variability as the main driving forces. In their model the climate sensitivity was also tested for various global radiation perturbations which are relevant for this study: stratospheric aerosol, tropospheric aerosol (divided into opposite sulfate and soot effects), and atmospheric trace gas content (carbon dioxide, ozone, methane and nitrous oxide). From this study it is conceivable that climate could be sensitive over the short term to the tropospheric and stratospheric aerosol loading. It may be possible to test the impact of a nuclear war on climate with this and similar models, when these are supplied with reasonable estimates of the trace gas and aerosol composition of the earth's atmosphere. Whether the induced perturbation in the climate system could lead to longer lasting climatic changes will, however, be difficult to predict. In fact, it may seem unlikely that it will take place. The Krakatoa volcanic eruption of 1883 injected quantities of aerosol into the atmosphere comparable to those which would be caused by a nuclear war, and global mean temperatures were affected for only a few years (1). Still, we must be cautious with a prediction as the physical characteristics of the aerosol produced by volcanoes and fires are different, and much is still unknown about the fundamentals of climatic changes. For instance, we may ask questions such as whether the earth's albedo would be substantially altered after a nuclear war and thus affect the radiation balance or whether the deposition of soot aerosol on arctic snow and ice and on the glaciers of the Northern Hemisphere might not lead to such heavy snow and ice melting as to cause an irreversible change in one or more important climatic parameters.

CONCLUSIONS

In this study we have shown that the atmosphere would most likely be highly perturbed by a nuclear war. We especially draw attention to the effects of the large quantities of highly sunlight-absorbing, dark particulate matter which would be produced and spread in the troposphere by the many fires that would start burning in

urban and industrial areas, oil and gas producing fields, agricultural lands, and forests. For extended periods of time, maybe months, such fires would strongly restrict the penetration of sunlight to the earth's surface and change the physical properties of the earth's atmosphere. The marine ecosystems are probably particularly sensitive to prolonged periods of darkness. Under such conditions it is likely that agricultural production in the Northern Hemisphere would be almost totally

eliminated, so that no food would be available for the survivors of the initial effects of the war. It is also quite possible that severe, worldwide photochemical smog conditions would develop with high levels of tropospheric ozone that would likewise interfere severely with plant productivity. Survival becomes even more difficult if stratospheric ozone depletions also take place. It is, therefore, difficult to see how much more than a small fraction of the initial survivors of a nuclear war in the

middle and high latitude regions of the Northern Hemisphere could escape famine and disease during the following year.

In this paper we have attempted to identify the most important changes that would occur in the atmosphere as a result of a nuclear war. The atmospheric effects that we have identified are quite complex and difficult to model. It is hoped, however, that this study will provide an introduction to a more thorough analysis of this important problem.

APPENDIX I

Production and Spatial Distribution of Nitric Oxide From Nuclear Explosions

There have been numerous estimates (43-46, 66) of the yield of nitric oxide per megaton (Mt) of explosion energy, and these have been reviewed by Gilmore (66). Nitric oxide is produced by heating and subsequent cooling of air in the interior of the fireball and in the shock wave.

The spherical shock wave produces nitric oxide by heating air to temperatures above 2200 K. This air is subsequently cooled by rapid expansion and radiative emission, while the shock front moves out to heat more air. At a particular temperature the cooling rate becomes faster than the characteristic time constant for maintaining equilibrium between NO and air. For cooling times of seconds to milliseconds the NO concentration "freezes" at temperatures between 1700 and 2500 K, corresponding to NO concentrations of 0.3-2 percent. Gilmore (66) estimates a yield of 0.8×10^{12} NO molecules per Mt for this mechanism.

The shock wave calculation of NO production does not take into account the fact that air within the fireball center contains approximately one-tenth of the initial explosion energy, having been heated by the radiative growth mechanism described earlier. This air cools on a time scale of several seconds by further radiative emission, entrainment of cold air, and by expansion as it rises to higher altitudes. These mechanisms are sufficiently complex that one can only estimate upper and lower limits to the quantity of NO finally produced.

A lower limit to total amount of NO finally produced may be obtained by assuming that all of the shock-heated air is entrained into the fireball and again heated to a high enough temperature to reach equilibrium. This is possible since the thickness of the shell of shock-heated air containing NO is smaller than the radius of the fireball. To minimize the cooling rate, and thus the temperature at which equilibrium is not re-established rapidly, it is assumed that this air mass cools only by adiabatic expansion as the fireball rises and by using a minimum rise velocity. The resulting lower limit to total NO production is 0.4×10^{12} molecules per Mt (66).

Since the interior of the fireball is much hotter than the surrounding, shock-heated air, it will rise much faster and possibly pierce through the shell of shock-heated air to mix with cold, undisturbed air above it. Thus, an upper limit to NO production may be obtained by assuming that none of the 0.8×10^{12} NO molecules per Mt produced in the shock wave are entrained by the hot fireball interior. Instead, one assumes that the interior is cooled totally by entrainment of cold, undisturbed air to produce additional NO. The upper limit to total NO production is then estimated to be 1.5×10^{12} molecules per Mt (66). Thus, the range of uncertainty for total NO_x formation is $0.4-1.5 \times 10^{12}$ molecules per Mt.

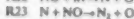
For the purposes of this study we assume a nitric oxide yield of 1.0×10^{12} molecules per Mt. One can make strong arguments against either of the extreme values. This estimate of NO production applies only to detonations in the lower atmosphere.

In a nuclear war some bombs may be exploded at very high altitudes for the purpose of disrupting radio and radar signals. The ionization of air by gamma rays, X-rays and charged particles creates a phenomenon

known as the "electromagnetic pulse" or "EMP" (67). The partitioning of energy between the locally heated fireball, shock wave, and escaping thermal radiation changes dramatically as the altitude of the explosion increases above 30 km. As the altitude increases, the X-rays are able to penetrate to greater distances in the low density air and thus create very large visible fireballs. For explosions above about 80 km, the interaction of the highly ionized weapon debris becomes the dominant mechanism for producing a fireball, and for such explosions the earth's magnetic field will influence the distribution of the late-time fireball. Explosions above 100 km produce no local fireball at all. Because of the very low air density, one-half of the X-rays are lost to space, and the one-half directed toward the earth deposits its energy in the so-called "X-ray pancake" region as they are absorbed by air of increasing density. The X-ray pancake is more like the frustum of a cone pointing upward, with a thickness of about 10 km and a mean altitude of 80 km. The mean vertical position is essentially independent of the explosion altitude for bursts well above 80 km (67).

The absorption of X-rays by air results in the formation of pairs of electrons and positively charged ions. One ion pair is formed for each 35 eV of energy absorbed (68), and in the subsequent reactions approximately 1.3 molecules of NO are produced for each ion pair (69). A 1-Mt explosion corresponds to 2.6×10^{16} eV of total energy. Thus, considering that only half of the X-rays enter the earth's atmosphere, the yield of NO is calculated to be 4.6×10^{12} molecules per Mt (so this mechanism is about five times more effective at producing NO than the thermal mechanism described above).

In the course of a nuclear war up to one hundred 1-Mt bombs might be detonated in the upper atmosphere for the purpose of creating radio wave disturbances. The injection of NO would therefore be 4.6×10^{12} molecules or 1.1 Tg of nitrogen. Natural production of NO in the thermosphere due to the absorption of EUV radiation depends on solar activity and is in the range 200-400 Tg of nitrogen per year (34). Thus the amount of NO injected by such high altitude explosions is about equal to the amount of NO produced naturally in one day and falls within the daily variability. In addition, the X-ray pancake is positioned at an altitude where nitrogen and oxygen species are maintained in photochemical equilibrium. Excess nitric oxide is rapidly destroyed by a sequence of reactions involving nitrogen and oxygen atoms as follows:



For these reasons, we expect that high altitude explosions of such magnitudes will have no significant global effect on the chemistry of the stratosphere and below.

Results of past tests of nuclear explosions show that nuclear clouds rise in the atmosphere and finally stabilize at altitudes that scale approximately as the 0.2 power of bomb yield. An empirical fit to observed cloud geometries at midaltitudes gives the following expressions for the heights of the cloud tops and cloud bottoms, respectively (44):

$$H_t = 22Y^{0.2}$$

$$H_b = 13Y^{0.2}$$

where H is in kilometers and Y has units of megatons. Thus, bomb clouds from weapons having yields greater than about 1 Mt completely penetrate the tropopause at midaltitudes. For such explosions all of the NO_x produced in the fireball, and perhaps a significant fraction of that produced in the shock wave but not entrained by the bomb cloud, is deposited in the stratosphere. Oxides of nitrogen formed in nuclear explosions having yields less than 1 Mt have little effect on stratospheric ozone since: 1) only a minor fraction of the NO_x formed is deposited above the tropopause, 2) the residence time in the stratosphere increases with altitude of injection, and 3) the NO_x catalytic cycle for ozone destruction is most effective at higher altitudes. In fact, below about 20 km NO_x additions to the atmosphere tend to result in ozone concentration increases (70, 71).

The stabilized nuclear bomb clouds have diameters ranging from 30 to 500 km depending on bomb yield. They are sheared by horizontal winds at constant latitude, and within a few weeks may be uniformly distributed around the earth at a constant latitude (72).

APPENDIX II

Model Description

The computer model used in this study is a two-dimensional model of coupled photochemistry and dynamics. It treats transport in both the vertical and latitudinal directions by parameterization of these motions by means of eddy diffusion coefficients and mean motions. The model covers altitudes between the ground and 55 km and latitudes between the South Pole and North Pole, and it attempts to simulate the longitudinally averaged, meridional distributions of trace gases. Therefore, the main assumption is that composition variations in the zonal (East-West) directions are much smaller than those in the vertical and latitudinal directions. Although the 2-D model is a step forward from 1-D models, which take into account only variations in the vertical direction, the neglect of longitudinal variations in air composition will clearly introduce substantial deviations from reality, especially at lower altitudes, where the influence of chemical and biological processes at the earth's surface are large. One should keep these limitations of the 2-D model in mind especially when interpreting the results obtained for the troposphere.

The model photochemistry considers the occurrence of nearly one hundred reactions, which are now thought to be important in global air chemistry. It takes into account the reactions of ozone and atomic oxygen, and the reactive oxides of nitrogen, hydrogen and chlorine, which are derived from the oxidation of nitrous oxide (N₂O), water vapor (H₂O), methane (CH₄) and organic chlorine compounds. In the troposphere, the photochemistry of simple reactions leading to ozone formation in the presence of NO_x, carbon monoxide (CO), methane and ethane (C₂H₆) are taken into account. The influence of industrial processes is an important consideration of the model. A more detailed description of the model may be found elsewhere (71, 72). Detailed descriptions of atmospheric photochemistry are given in a number of review articles (34, 73-75).

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